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(54) **CONTACT TIP STRUCTURES FOR MICROELECTRONIC INTERCONNECTION ELEMENTS AND METHODS OF MAKING SAME**

KONTAKTSPITZENSTRUKTUR FÜR MIKROELEKTRONISCHE VERBINDUNGSELEMENTE UND HERSTELLUNGSVERFAHREN DAZU

STRUCTURES A POINTES DE CONTACT POUR ELEMENTS D'INTERCONNEXION MICRO-ELECTRONIQUES ET PROCEDES DE FABRICATION CORRESPONDANT

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(56) References cited:
WO-A-91/12706 WO-A-94/09513
WO-A-95/14314 WO-A-96/37332
US-A- 5 191 708 US-A- 5 391 521
US-A- 5 469 733

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The invention relates to interconnection (contact) elements for microelectronic applications and, more particularly, to contact elements which are resilient (springy) contact elements suitable for effecting pressure connections between electronic components.

BACKGROUND OF THE INVENTION

[0002] Generally, interconnections between electronic components can be classified into the two broad categories of "relatively permanent" and "readily demountable".

[0003] An example of a "relatively permanent" connection is a solder joint. Once two electronic components are soldered to one another, a process of unsoldering must be used to separate the components. A wire bond, such as between a semiconductor die and inner leads of a semiconductor package (or inner ends of leadframe fingers) is another example of a "relatively permanent" connection.

[0004] An example of a "readily demountable" connection is rigid pins of one electronic component being received by resilient socket elements of another electronic component.

[0005] Another type of readily demountable connection is interconnection elements which themselves are resilient, or springy, or are mounted in or on a springy medium. An example of such a spring contact element is a tungsten needle of a probe card component. Such spring contact elements are intended to effect typically temporary pressure connections between a component to which they are mounted and terminals of another component, such as a semiconductor device under test (DUT). Problems with tungsten needles include difficulties in grinding their tips to have an appropriate shape, they don't last long, and they require frequent rework.

[0006] Generally, a certain minimum contact force is desired to effect reliable pressure contact to electronic components (e.g., to terminals on electronic components). For example, a contact (load) force of approximately 15 grams (including as little as 2 grams or less and as much as 150 grams or more, per contact) may be desired to ensure that a reliable electrical pressure connection is made to a terminal of an electronic component which may be contaminated with films on the surface of its terminals, or which has corrosion or oxidation products on its surface.

[0007] In addition to establishing and maintaining an appropriate minimum contact force, another factor of interest is the shape (including surface texture) and metallurgy of the ends of the spring contact element making pressure connections to the terminals of the electronic components. Returning to the example of tungsten needles as probe elements, the metallurgy of the contact end is evidently limited by the metallurgy (i.e., tungsten) of

the interconnection element and, as these tungsten needles become smaller and smaller in diameter, it becomes commensurately more difficult to control or establish a desired shape at their contact ends.

[0008] In certain instances, the contact elements themselves are not resilient, but rather are supported by a resilient member. Membrane probes exemplify this situation, wherein a plurality of microbumps are disposed on a resilient membrane. Again, the technology required to manufacture such interconnection elements limits the design choices for the shape and metallurgy of the contact portions of such interconnection elements.

[0009] An example of an elongate spring contact element is disclosed in the PARENT CASE (PCT/US95/14909) which describes the fabrication of resilient contact structures (spring elements) as "composite" interconnection elements by mounting a free-standing wire stem (elongate element) on a terminal of an electronic component, shaping the wire stem, severing the wire stem to be free-standing, and overcoating the free-standing wire stem to impart the desired resiliency to the resulting free-standing spring element. The overcoat material also extends contiguously over the adjacent surface of the terminals to which the wire stems are mounted to provide firmly anchor the resulting composite interconnection elements to the terminals. Although these elongate, composite, resilient interconnection elements will benefit from the present invention, the present invention is not limited thereto.

[0010] WO 95/14314 A1 discloses a contact structure for interconnecting two separate electronic components. In one embodiment the contact structure includes free-standing bond wires which are covered by a resilient layer. The bond wires extend from the contact on the surface of one electronic component and have a distal contact end to make a connection to a contact terminal on a second electronic component opposite to the first electronic component. In another embodiment a bond wire is first fixed to a gold pad formed on a sacrificial substrate and in a wire bond process the wire is drawn to a contact pad on an electronic component where the other end of bond wire is fixed to. The bond wire may be covered with a spring material. The contact pad in the sacrificial substrate is released by removing the sacrificial substrate.

[0011] The earlier application WO 96/37332 A1 falls under the provision of Article 54(3) EPC and proposes the the fabrication of a contact structure using a sacrificial substrate.

[0012] It is an object of the invention to provide methods of fabricating interconnection devices or tip structures and of interconnecting electronic components as well as corresponding tip structures, resulting in improved contacting properties of the interconnection devices or structures when contacting an electronic component, particularly in use in interconnecting microelectronic components.

[0013] The invention is defined in claims 1, 19, 28, 46 and 47, respectively.

[0014] Particular embodiments are set out in the dependent claims.

[0015] According to the invention, contact tip structures are pre-fabricated on sacrificial substrates, and subsequently are joined to other (existing) interconnection elements, after which the sacrificial substrate is removed (separated from the resulting "tipped" interconnection elements).

[0016] Said interconnection elements may or may not be elongate, and may or may not be resilient (spring) contact elements. Said interconnection elements may be "composite" or "monolithic", and include tungsten needles of probe cards and bump elements of membrane probes.

[0017] According to a feature of the invention, the contact tip structures are joined by brazing or by plating to the interconnection elements. Alternatively, the contact tip structures can be joined to the interconnection elements with a conductive adhesive (e.g., silver-filled epoxy) or the like.

[0018] According to a feature of the invention, various metallurgies and topologies (contact features) are described for the contact tip structures.

[0019] According to an aspect of the invention, a plurality of contact tip structures are readily fabricated on a sacrificial substrate to extremely close tolerances using conventional semiconductor processing techniques (e.g., photolithography, deposition), including micromachining techniques, as well as "mechanical" techniques, so as to have a prescribed spatial relationship with one another. So long as the contact tip structures remain resident on the sacrificial substrate, these tolerances and spatial relationships are well preserved. After the contact tip structures are joined with interconnection elements, these tolerances will be preserved by the interconnection elements.

[0020] Generally, the invention facilitates the construction of electrical contact structures by joining a plurality of contact tip structures having a relatively precise positional relationship with one another to a corresponding plurality of interconnection elements which may be disposed in relatively rough (coarse) relationship with one another. Preferably, each contact tip structure has a topological contact feature portion on its body portion which is disposed in relatively precise relationship to other ones of the topological contact features, so that the body portions of the tip structures need not be located so precisely with respect to one another. These topological contact features are readily formed with great positional precision by etching the sacrificial substrate upon which the contact tip structure is pre-fabricated so that they take the form (shape) of pyramids, truncated pyramids, and the like, using conventional semiconductor fabrication processes including micromachining.

[0021] According to a feature of the invention, various sacrificial substrates are described, as well as methods for separating the pre-fabricated contact structures from the sacrificial substrates upon which they are resident.

[0022] For example, the sacrificial substrate may be a silicon wafer which is processed using micromachining techniques to have depressions, including features, wherein the contact tip structures of the present invention are fabricated by depositing one or more conductive metallic layers into the depressions and features.

[0023] The invention permits contact tip structures to be pre-fabricated which have surface texture (roughness and shape; geometry, topology), and metallurgy, and which are of a size that are not limited by the materials and considerations attendant the manufacture of the interconnection elements to which they are joined. A sacrificial substrate upon which a plurality of contact tip structures have been pre-fabricated is suitably sold as a finished product, in and of itself, to others who desire to join the contact tip structures to their interconnection elements.

[0024] An important feature of the present invention is that a plurality of contact tip structures are readily fabricated on a sacrificial substrate to extremely precise tolerances, for example, by using known semiconductor fabrication processes such as masking, lithography and deposition to control their size and spacing.

[0025] According to an aspect of the invention, elongate contact tip structures are fabricated which, in and of themselves, are suited in use to function as spring contact elements, without requiring joining to existing interconnection elements.

[0026] These elongate contact tip structures which function as spring contact elements can be flat, and joined at their base ends to conductive pedestals on a surface of an electronic component so that there is a space between the elongate contact tip structure and the surface of the electronic component within which the contact end of the elongate contact tip structure may deflect.

[0027] These elongate contact tip structures which function as spring contact elements may also be three-dimensional in that their base ends are offset in a one direction from their central body portions and so that their contact ends are offset in an opposite direction from their central body portions.

[0028] The elongate contact tip structures of the present invention can have alternating orientations (e.g., left-right-left-right) so as to achieve a greater (coarser) pitch between their base ends than at their contact ends.

[0029] The elongate contact tip structures of the present invention can have alternating lengths (e.g., short-long-short-long) so as to achieve a greater (coarser) pitch between their base ends than at their contact ends.

[0030] Tapering the width and/or thickness of elongate contact tip structures between their base ends and their contact ends is disclosed.

[0031] Techniques are disclosed for tailoring (adjusting) the force which elongate contact tip structures will exert in response to contact forces applied at their contact ends.

[0032] The present invention provides a technique for

fabricating relatively 'perfect' (extremely uniform and reproducible to close tolerances) contact tip structures and 'marrying' them to relatively 'imperfect' interconnection elements. Due to the constraints associated with making interconnection elements, certain tradeoffs are often required vis-a-vis the tip geometry and metallurgy, and overall spatial uniformity of the interconnection elements. And, if they can't be reworked, they must be replaced. The present invention solves this limitation by freeing up the tip metallurgy, geometry, and topology from that of the interconnection element to which it is joined, with lithographically precise uniformity.

[0033] Other objects, features and advantages of the invention will become apparent in light of the following description thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Reference will now be made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Although the invention will be described in the context of these preferred embodiments, it should be understood that it is not intended to limit the spirit and scope of the invention to these particular embodiments.

[0035] In the side views presented herein, often only portions of the side view are presented in cross-section, and portions may be shown in perspective, for illustrative clarity.

[0036] In the figures presented herein, the size of certain elements are often exaggerated (not to scale, vis-a-vis other elements in the figure), for illustrative clarity.

Figure 1A is a perspective view, partially exploded, of an exemplary embodiment of the invention, illustrating pre-fabricated contact tip structures and interconnection elements to which they will be joined.

Figure 1B is a side cross-sectional view of the contact tip structures of **Figure 1A** joined by brazing to the interconnection elements of **Figure 1A**.

Figure 1C is a side cross-sectional view, partially in perspective, of the contact tip structures of **Figure 1A** joined by plating to the interconnection elements of **Figure 1A**.

Figure 1D is a side cross-sectional view of the contact tip structures of **Figure 1A** joined by brazing (compare **Figure 1B**) to the interconnection elements of **Figure 1A**, after the sacrificial substrate is removed.

Figure 2A is a cross-sectional view of a technique for fabricating contact tip structures for interconnection elements for illustrative purposes.

Figure 2B is a cross-sectional view of further steps in the technique of **Figure 2A**.

Figure 2C is a side view, partially in cross-section, of the contact tip structures of **Figure 2B** being joined to existing interconnection elements.

Figure 2D is a side view, partially in cross-section, of a further (final) step in joining the interconnection elements of **Figure 2C** joined with the contact tip structures of **Figure 2B**, after removal of the sacrificial substrate.

Figure 3A is a side, cross-sectional view of an exemplary, illustrative embodiment wherein the contact tip structures of the present invention are affixed to a type of elongate interconnection elements.

Figure 3B is a side, cross-sectional view of another embodiment wherein the contact tip structures of the present invention are affixed to a type of elongate interconnection elements.

Figure 3C is a side, cross-sectional view of another embodiment wherein the contact tip structures of the present invention are affixed to a type of interconnection elements,

Figure 4A is a side cross-sectional view of a technique for fabricating a multilayer contact tip structure.

Figure 4B is a side cross-sectional view of a technique for forming a contact tip structure on a sacrificial substrate (424) and a technique for releasing the sacrificial substrate.

Figure 5A is a perspective view of a first step in fabricating a plurality of contact tip structures on a sacrificial substrate, according to the invention.

Figure 5B is a side cross-sectional view, taken on the line 5B-5B through **Figure 5A**, of another step in fabricating contact tip structures on a sacrificial substrate, according to the invention.

Figure 5C is side cross-sectional view of another step in fabricating contact tip structures on a sacrificial substrate, according to the invention.

Figure 5D is a side cross-sectional view of a contact tip structure which has been fabricated on a sacrificial substrate, according to the invention.

Figure 5E is a perspective view of a contact tip structure which has been joined to an interconnection element, according to the invention.

Figure 5F is a side cross-sectional view of a contact

tip structure which has been joined to a different interconnection element.

Figure 6A is perspective view of a technique for preparing a sacrificial substrate for the fabrication of a contact tip structure, according to the invention.

Figure 6B is a perspective view of a contact tip structure joined to an end of an interconnection element (shown in dashed lines), according to the invention.

Figures 7A-7C are cross-sectional views of steps in a process of manufacturing elongate contact tip structures on a sacrificial substrate according to the invention.

Figure 7D is a perspective view of an elongate contact tip structure formed on a sacrificial substrate, according to the invention.

Figure 7E is a perspective view of a plurality of elongate contact tip structures formed on a sacrificial substrate, according to the invention.

Figure 7F is a side cross-sectional view, of a technique for mounting elongate contact tip structures to an electronic component.

Figure 8 is a perspective view of an embodiment illustrating the fabrication of a plurality of elongate contact tip structures having alternating lengths, according to the invention.

Figure 9A is a cross-sectional view of an elongate contact tip structure suitable for use as a resilient interconnection element (spring contact element), according to the invention.

Figure 9B is a plan view of the spring contact element of **figure 9A**, according to the invention.

Figure 9C is a cross-sectional view of an alternate embodiment of a spring contact element, according to the invention.

Figure 9D is an enlarged cross-sectional view of a portion of the spring contact element of **Figure 9C**.

Figure 9E is a cross-sectional view of an alternate embodiment of a spring contact element, according to the invention.

Figures 10A-10D are side cross-sectional views of alternate techniques for tailoring the mechanical characteristic of elongate contact tip structures (spring contact elements)

Figures 11A and 11B are perspective views of al-

ternate spring contact elements, according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0037] The present invention is generally directed to pre-fabricating contact tip structures, and subsequently joining them to existing interconnection elements so as to obtain one or more of the following benefits:

(a) the contact tip structures of the present invention are readily provided with a distinct surface texture, roughness and shape (geometry, topology) which is specifically adapted to the terminal metallurgy of the electronic component(s) ultimately being contacted by the tips of the interconnection elements to which they are joined, independent of the surface texture of the interconnection elements to which they are joined, to optimize pressure connections being made by the "tipped" interconnection elements with specific terminals of electronic components for different applications;

(b) the contact tip structures of the present invention are readily fabricated with any suitable metallurgy, including entirely independent of and dissimilar from that of the interconnection elements to which they are joined; and

(c) the contact tip structures of the present invention are readily fabricated to extremely precise tolerances, with respect to the planarity of a plurality of contact tip structures and with regard to the spacing between individual ones of the plurality of contact tip structures, virtually independent of tolerance limitations attendant to the interconnection elements to which they are joined; and

(d) the contact tip structures of the present invention are readily fabricated to have a critical dimension (e.g., diameter) which is independent of and larger than a corresponding dimension (e.g., cross-section diameter) of the interconnection elements to which they are joined.

[0038] Existing interconnection elements such as elongate and/or resilient interconnection elements will benefit from having the contact tip structures of the present invention joined thereto.

A "GENERALIZED" EMBODIMENT

[0039] **Figure 1A** illustrates an illustrative embodiment 100 for explaining the inventions field wherein a plurality (four of many shown) of contact tip structures 102 have been pre-fabricated upon a support (sacrificial) substrate 104, in a manner described hereinbelow. A corresponding plurality (four of many shown) of interconnection elements 106 (only the distal ends and tips of these elongate interconnection elements are illustrated) are shown in preparation for having their free ends 106a joined to

the contact tip structures 102 (or vice-versa). The free ends 106a of the elongate interconnection elements 106 are distant (distal) from opposite ends (not shown) of the elongate interconnection elements 106 which typically would extend from a surface of an electronic component (not shown) such as a semiconductor device, a multilayer substrate, a semiconductor package, etc.

[0040] The support (sacrificial) substrate 104 with pre-fabricated contact tip structures 102 resident thereon is fabricated separately from, prior to, and by an entirely different process than, the elongate interconnection elements 106.

[0041] Figure 1B illustrates, in side view, a next step of joining the contact tip structures 102 to the elongate interconnection elements 106 by brazing. A resulting braze fillet 108 is illustrated. The contact tip structures 102 are still resident on the sacrificial substrate 104 in their prescribed spatial relationship with one another. Figure 1B is also illustrative of the contact tip structures 102 being joined to the elongate interconnection elements with conductive adhesive (e.g., silver-filled epoxy) or the like.

[0042] Figure 1C illustrates, in side view, an alternate next step of joining the contact tip structures 102 to the elongate interconnection elements 106 by overcoating at least the junction of the contact tip structures 102 and adjacent end portions of the elongate interconnection elements 106 with a metallic material 110 such as nickel, such as by plating. Although not specifically shown, it should be understood that the overcoating material 110 may extend along (cover) the full length of the elongate interconnection element 106.

[0043] Figure 1D illustrates, in side view, a step subsequent to the steps illustrated in either of Figures 1B or 1C wherein, after joining the contact tip structures 102 to the elongate interconnection elements 106, the support (sacrificial) substrate 104 is removed. Techniques for removing the sacrificial substrate are described hereinbelow. The resulting "tipped" interconnection element 106 (as used herein, a "tipped" interconnection element is an interconnection element which has had a separate contact tip structure joined thereto) is shown as having had a contact tip structure 102 brazed (108) thereto, in the manner described with respect to Figure 1B.

[0044] In this manner, the contact tip structures 102 can be at different (more precise) tolerance spacing than the interconnection elements 106, can have different metallurgy than the interconnection elements 106, and can have a topology (described hereinbelow) which is not otherwise attainable for the interconnection elements 106.

[0045] Materials for the contact tip structures (102) and the sacrificial substrate (104), as well as suitable techniques for pre-fabricating the contact tip structures (102) and for removing the sacrificial substrate after joining the contact tip structures (102) to the interconnection elements (106), are described in greater detail hereinbelow.

AN INTRODUCTION TO PRODUCTION METHOD, AND RESULTING "TIPPED" INTERCONNECTION ELEMENTS

5 [0046] As mentioned hereinabove, many advantages accrue to prefabricating contact tip structures (on a sacrificial substrate) and subsequently joining the contact tip structures to interconnection elements which have been fabricated separately from the contact tip structures.

10 [0047] Figures 2A-2D illustrate a technique for prefabricating contact tip structures on a sacrificial substrate, joining the contact tip structures to the exemplary elongate interconnection elements, and removing the sacrificial substrate.

15 [0048] Figure 2A illustrates a technique 200 for fabricating contact tip structures on a sacrificial substrate 202. In this example, a silicon substrate (wafer) 202 having a top (as viewed) surface is used as the sacrificial substrate. A layer 204 of titanium is deposited (e.g., by sputtering) onto the top surface of the silicon substrate 202, and suitably has a thickness of approximately 25 nm (250 Å; $1\text{ Å} = 0.1\text{ nm} = 10^{-10}\text{ m}$). A layer 206 of aluminum is deposited (e.g., by sputtering) atop the titanium layer 204, and suitably has a thickness of approximately 2,000 nm (20,000 Å). The titanium layer 204 is optional and serves as an adhesion layer for the aluminum layer 206. A layer 208 of copper is deposited (e.g., by sputtering) atop the aluminum layer 206, and suitably has a thickness of approximately (5,000 Å) 500 nm.

20 [0049] A layer 210 of masking material (e.g., photoresist) is deposited atop the copper layer 208, and has a thickness of approximately $50.8\text{ }\mu\text{m}$ (2 mils). The masking layer 210 is processed in any suitable manner to have a plurality (three of many shown) of holes (openings) 212 extending through the photoresist layer 210 to the underlying copper layer 208. For example, each hole 212 may be $152.4\text{ }\mu\text{m}$ (6 mils) in diameter, and the holes 212 may be arranged at a pitch (center-to-center) of $254\text{ }\mu\text{m}$ (10 mils). The sacrificial substrate 202 has, in this manner, been prepared for fabricating a plurality of contact tip structures at what are "lithographically-defined" locations on the sacrificial substrate 202, within the holes 212. Exemplary contact tip structures may be formed, as follows:

25 [0050] A layer 214 of nickel is deposited, such as by plating, within the holes 212, onto the copper layer 208, and suitably has a thickness of approximately $25.4\text{--}38\text{ }\mu\text{m}$ (1.0 -1.5 mils). Optionally, a thin layer (not shown) of a noble metal such as rhodium can be deposited onto the copper layer 208 prior to depositing the nickel. Next, a layer 216 of gold is deposited, such as by plating, onto the nickel 214. The multi-layer structure of nickel and gold (and, optionally, rhodium) will serve as a prefabricated contact tip structure (220, as shown in Figure 2B).

30 [0051] Next, as illustrated in Figure 2B, the photoresist 210 is stripped away (using any suitable solvent), leaving a plurality of pre-fabricated tip structures 220 sitting atop the copper layer 208. Next, the exposed (i.e., not covered

by contact tip structures 220) portion of the copper layer 208 is subjected to a quick etch process, thereby exposing the aluminum layer 206. As will be evident, aluminum is useful in subsequent steps, since aluminum is substantially non-wettable with respect to most solder and braze materials.

[0052] It bears mention that it is preferred to pattern the photoresist with additional holes (not shown, comparable to 212) within which "ersatz" contact tip structures 222 may be fabricated in the same process steps employed to fabricate the actual contact tip structures 220. These ersatz contact tip structures 222 will serve to uniformize the aforementioned plating steps (214, 216) in a manner that is well known and understood, by reducing abrupt gradients (non-uniformities) from manifesting themselves across the surface being plated. Such structures (222) are typically referred to in the field of plating as "robbers".

[0053] In this manner, a plurality of contact tip structures 220 have successfully been pre-fabricated on a sacrificial substrate 202, awaiting subsequent joining to a corresponding plurality of interconnection elements. Optionally, as part of the prefabrication of contact tip structures (alternatively, immediately prior to joining the contact tip structures to the interconnection elements), solder or brazing paste ("joining material") 224 is deposited onto the top (as viewed) surfaces of the tip structures 220. (There is no need to deposit the paste onto the tops of the ersatz tip structures 222). This is implemented in any suitable manner, such as with a stainless steel screen or stencil or by automated dispensing of solder paste, as is known in the art. A typical paste (joining material) 224 would contain gold-tin alloy (in a flux matrix) exhibiting, for example, 25.4 μm (1 mil) spheres (balls).

[0054] The contact tip structures 220 are now ready to be joined (e.g., brazed) to ends (tips) of interconnection elements.

[0055] The contact tip structures (220), as fabricated upon and resident upon a sacrificial substrate (202), constitute a product in and of itself and, as described in greater detail hereinbelow, can subsequently be joined to a wide variety of pre-existing interconnection elements.

[0056] The sacrificial substrate with contact tip structures resident thereon is now brought to bear upon tips (free ends) of exemplary elongate interconnection elements 252 extending from an exemplary substrate 254 which may be an electronic component. As shown in Figure 2C, the contact tip structures 220 (only two contact tip structures are shown in the view of Figure 2D, for illustrative clarity) are aligned with the tips (distal ends) of the interconnection elements 252, using standard flip-chip techniques (e.g., split prism), and the assembly is passed through a brazing furnace (not shown) to reflow the joining material 224, thereby permanently joining (e.g., brazing) the prefabricated contact tip structures 220 to the ends of the interconnection elements 252.

[0057] During the reflow process, the exposed aluminum layer (206), being non-wettable, prevents solder

(i.e., braze) from flowing between the contact tip structures 220, i.e., prevents solder bridges from forming between adjacent contact tip structures.

[0058] In addition to this anti-wetting function of the aluminum layer 206, the aluminum layer 206 also serves to provide a release mechanism. Using a suitable etchant, the aluminum is preferentially (to the other materials of the assembly) etched away, and the silicon sacrificial substrate 202 simply "pops" off, resulting in a substrate or electronic component 254 having "tipped" interconnection elements 252, each having a prefabricated tip structure 220, as illustrated in Figure 2D. (Note that the joining material 224 has reflowed as "fillets" 225 on end portions of the interconnection elements 252.)

[0059] In a final step of the process, the residual copper (208) is etched away, leaving the contact tip structures 220 with nickel (or rhodium, as discussed hereinabove) exposed for making reliable electrical pressure connections to terminals (not shown) of other electronic components (not shown).

[0060] It is within the scope of the invention that the brazing (soldering) paste (224) is omitted, and in its stead, alternating layers of gold and tin in a eutectic ratio are plated onto the interconnection elements (252) prior to mounting the contact tip structures (220) thereto. In a similar manner, eutectic joining layers can be plated onto the contact tip structures (220) prior to joining with the interconnection elements (252).

[0061] Since the contact tip structures (220) are readily fabricated to be coplanar and of uniform thickness, the resulting "tipped" interconnection elements (Figure 2D) will have tips (i.e., the exposed surfaces of the contact tip structures) which are substantially coplanar.

[0062] The electronic component (e.g., 254) to which the interconnection elements (e.g., 252) are mounted may be an ASIC, a microprocessor, a component (e.g., space transformer component) of a probe card assembly, and the like.

EXAMPLES

[0063] It is within the scope of this invention that the techniques disclosed herein can be used to join (e.g., braze) pre-fabricated contact tip structures to interconnection elements which are either resilient or non-resilient, and which are elongate, and which are either composite interconnection elements (such as are disclosed in the PARENT CASE PCT/US95/14909) or monolithic interconnection elements, and the like. The interconnection elements to which the contact tip structures are joined may be mounted to (extending from) a substrate such as an electronic component (such as, but not limited to the space transformer of a probe card assembly such as is disclosed in the aforementioned PCT/US95/14844), or may be a plurality of interconnection elements which are not mounted to a substrate but which are maintained by some other means in a prescribed spatial relationship to one another.

[0064] Figures 3A, 3B and 3C illustrate a few of such exemplary applications wherein the prefabricated contact tip structures (e.g., 220) of the present invention, are joined to different types of "existing" (fabricated separately) interconnection elements. In these figures, brazing is omitted, for illustrative clarity.

EXAMPLE 1

[0065] An example of a plurality of elongate interconnection elements which are not mounted by their ends to a substrate is the IBM (tm) Cobra (tm) probe which, as shown (stylized) in Figure 3A, has a plurality (four of many shown) of elongate interconnection elements 302 extending generally parallel to each other between two rigid fixed planar structures 304 and 306, the two opposite ends of each interconnection element 302 being exposed through a respective one of the two rigid fixed planar structures for making a pressure connection between a terminal (not shown) of a one electronic component (not shown) and a terminal (not shown) of another electronic component (not shown). The illustration of Figure 3A is schematic in nature, and is not intended to be a mechanical assembly drawing. The elongate interconnection elements 302 can be kinked, and generally function as buckling beams.

[0066] Prefabricated contact tip structures, for example the tip structures 220 shown in Figure 2B hereinabove, are readily joined (such as by brazing or plating, discussed hereinabove, not shown) to one end (not shown) or to both ends (as shown) of the interconnection elements 302, as illustrated in Figure 3A, after which the sacrificial substrate (e.g., 202) is removed (not shown). For example, if the tip structures 220 are joined to only one end of the interconnection elements, they would preferably be joined to a common (e.g., top, as viewed in the figure) end of the interconnection elements.

[0067] This illustrates important advantages of the present invention. The metallurgy, size and topology of the contact tip structures (220) is entirely independent of the physical characteristics of the elongate interconnection elements (302) to which they are joined, as well as being independent of any processes limitations attendant the assembly of such a plurality of interconnection elements into a useful apparatus.

[0068] The present invention overcomes problems associated with Cobra-type interconnection elements which require careful shaping of their tips to be effective.

EXAMPLE 2

[0069] Figure 3B illustrates a one of a plurality of contact tip structures 220 joined (such as by brazing or plating, discussed hereinabove, not shown) to an end of an elongate tungsten needle 312 which is a typical element of a prior art probe card (not shown).

[0070] This illustrates, in an exemplary manner, an important advantage of the present invention. It is generally

difficult to provide existing tungsten needles of probe cards with a desired tip shape, especially as the needles are getting smaller and smaller in size (e.g., having a diameter of 25.4 μm (1 mil)). By joining prefabricated contact tip structures (220) to the ends of tungsten needles (312), these problems may be avoided, thereby facilitating the use of ever smaller (e.g., in diameter) tungsten needles while providing contact surfaces (i.e., of the contact tip structures) which are larger (in diameter, or "footprint") than the tungsten needles. The present invention also overcomes, for example, the difficulty in controlling the shape and exact location of the tips (ends) of the tungsten needles.

[0071] The present invention overcomes various problems associated with tungsten needle probe elements, including difficulties in grinding their tips to have an appropriate shape and longevity.

[0072] In the case of certain interconnection elements, it may be desirable to prepare the surface of the interconnection elements for joining contact tip structures thereto, such as by appropriate plating procedures, to make the surface of the interconnection elements receptive to brazing (or plating). For example, plating tungsten needles (e.g., 312) of a probe card insert with gold, nickel, nickel-palladium, etc. prior to joining contact tip structures (e.g., 220) thereto.

EXAMPLE 3

[0073] The interconnection elements to which the contact tip structures are joined will be elongate, and may be inherently resilient, such as in the previous two examples. It is, however, within the scope of the present invention that the interconnection elements to which the contact tip structures are joined are not inherently resilient.

[0074] Figure 3C illustrates a portion of a membrane probe of the type known in the prior art wherein a plurality (two of many shown) of non-resilient bump interconnection elements (contact bumps) 322 are resident on a surface of a flexible membrane 324. As illustrated, the contact tip structures of the present invention, for example the tip structures 220 are joined (such as by brazing or plating, discussed hereinabove, not shown) to the interconnection elements 322. For purposes of this discussion, the rounded bumps 322 are considered to have "tips" or "ends" at their apex (their top edge, as viewed).

[0075] The ability to join contact tip structures (220) to the interconnection elements of such membrane probes permits entirely different processes and metallurgies to be employed in the fabrication of the contact tip structures and the bump contacts themselves.

[0076] The contact tip structure (220) overcomes problems associated with the semi-spherical contact bumps of membrane probes which cannot generally be reworked.

[0077] As will be discussed in greater detail hereinbelow, the present invention also permits a virtually uncon-

strained desired surface texture to be achieved in the pressure-contacting surface of the tipped interconnection element.

METALLURGY OF THE CONTACT TIP STRUCTURE

[0078] Various metallurgies (metal recipes) for the contact tip structures of the present invention have been described hereinabove. It is within the scope of this invention that any metallurgy suited to the ultimate application of the resulting "tipped" interconnection element be employed.

[0079] As illustrated in **Figure 4A**, a useful (e.g., preferred) contact tip structure for an interconnection element can be formed in (or on) a sacrificial substrate, in the following manner, using a thin aluminum (foil) as the sacrificial substrate 400:

- provide a temporary backing 402, such as a plastic sheet, for the foil 400, to increase the structural integrity of the foil (this backing layer 402 can also act as a plating barrier/mask);
- pattern the face (top, as viewed) of the foil 400 with a thin (approximately 76 μm (**3 mil**)) layer of photoresist 404, or the like, leaving (or creating) openings at locations (compare 212) whereat it is desired to form contact tip structures;
- deposit (such as by plating) a thin (approximately 2.54 μm (**100 microinch** (μm))) layer 406 of hard gold onto the foil 400, within the openings in the photoresist 404;
- deposit (such as by plating) a very thin (approximately 5-10 μm) layer ("strike") of copper 408 onto the layer of hard gold (it should be understood that such a copper strike is somewhat optional, and is provided principally to assist in subsequent plating of the previous gold layer 406);
- deposit (such as by plating) a relatively thick (approximately 50.8 μm (**2 mil**)) layer 410 of nickel onto the copper strike; and
- deposit (such as by plating) a thin (approximately 2.54 μm (**100 μ**)) layer 412 of soft gold onto the nickel.

[0080] This results in a multilayer contact tip structure 420 (compare 220), which is readily joined to an end of an interconnection element (not shown). The contact tip structure 420 has, as its principal layers, a hard gold surface (406) for contacting (e.g., making pressure connections to) electronic components (not shown), a nickel layer (410) providing strength, and a soft gold layer (412) which is readily bonded to (joinable to) an interconnection element.

[0081] Regarding depositing the materials (e.g., 214, 216; 406, 408, 410, 412) for the contact tip structure into the openings of the masking material atop the sacrificial substrate, it should be noted that the sacrificial substrate itself (e.g., 400), or one or more of the blanket layers

deposited thereon (e.g., 206, 208) serve to electrically connect the openings to one another, thereby facilitating the use of electroplating processes.

5 RELEASING THE SACRIFICIAL SUBSTRATE

[0082] As mentioned hereinabove, a "plain" (i.e., no active devices resident thereupon) silicon wafer can be used as the sacrificial substrate upon which the contact tip structures of the present invention may be fabricated. An exemplary metallurgy is set forth hereinabove, wherein using a suitable chemical selective etching process, the contact tip structures are released from the sacrificial substrate.

15 [0083] It is within the scope of this invention that an appropriate metallurgy in conjunction with heat can be used to release the sacrificial substrate, rather than a chemical etchant. For example, as illustrated by **Figure 4B**:

Step 1. Etch pits (one of one or more shown) 422 into a silicon (sacrificial) substrate 424 at locations (one of several shown) whereat it is desired to have topological features on contact tip structures. As discussed hereinbelow, etching of silicon can be self-limiting.

Step 2. Apply a patterned masking layer 426 (e.g., photoresist) onto the surface of the silicon (sacrificial) substrate 424. Openings 428 in the masking layer are at locations where the contact tip structures will be fabricated.

Step 3. Deposit (such as by sputtering) a thin layer 430 of a (as will be evident, non-wettable) material such as tungsten (or titanium-tungsten) onto the substrate, within the openings 428 of the masking layer 426.

Step 4. Deposit (such as by sputtering) a thin layer 432 of a non-wetting material such as plateable lead (or indium) onto the thin tungsten layer, within the openings 428 of the mask 426.

Step 5. Fabricate the contact tip structures 440 (compare 220, 420) having one or more layers within the openings of the mask, in the manner described hereinabove (e.g., with respect to **Figure 4A**).

Step 6. Reflow (using heat) the contact tip structures 440 onto interconnection elements (not shown) in the manner described hereinabove. During reflow, the lead (material 432) will melt and ball up, since tungsten (430) is not wettable with respect to lead (432). This will cause the contact tip structures 440 to be released from the sacrificial substrate 424.

[0084] Optionally, a second layer of non-wettable material (e.g., tungsten) can be applied over the layer 432. Said material will become part of the resulting contact tip structure, unless it is removed (e.g., by etching). In some cases, lead will not ball up (e.g., lead tends to wet nickel), in which cases it may be desired to put additional layers

such as lead, then tungsten, then lead, to ensure proper release of the contact tip structures from the sacrificial substrate.

[0085] Optionally, another layer of material which will ball up when heated (e.g., lead, indium) can be applied over the second layer of non-wettable material (e.g., tungsten). Any residual lead on the surface of the resulting contact tip structure is readily removed, or may be left in place. Alternatively, a layer of a "barrier" material can be deposited between the second layer of material which will ball up and the first layer (e.g., rhodium) of the fabricated contact tip structure 1420. The "barrier" material may be tungsten, silicon nitride, molybdenum, or the like.

TIP TOPOLOGY (Surface Topography)

[0086] In the main hereinabove, contact tip structures (e.g., 102, 220, 440) which have a flat contact surface have been discussed. For many pressure contact applications, a spherical or very small surface area contact tip urging against a nominally flat-surfaced terminal of an electronic component is preferred. In other applications, the surface of the contact tip structure will preferably have projections in the shape of a pyramid, a truncated pyramid, a cone, a wedge, or the like.

[0087] Figure 5A illustrates a first step in a technique 500 for forming elongate contact tip structures having pyramid or truncated pyramid contact features on a sacrificial substrate 502 which is a silicon wafer. A layer 504 of masking material, such as photoresist, is applied to the surface of the silicon substrate 502, and is patterned to have a plurality (two of many shown) of openings 506 extending to the surface of the silicon substrate 502. The openings 506 are preferably square, measuring approximately 25.4-101.6 μm (1-4 mils), such as 63.5 μm (2.5 mils) on a side. However, the openings may be rectangular, or may have other geometric shapes.

[0088] Next, as illustrated in Figure 5B, the silicon substrate 502 is etched to form a like plurality (one of many shown) of pyramid-shaped depressions 508 in the silicon. Such etching of silicon will tend to be self-limiting, as the etching proceeds along the crystal plane at 54.74° for (100) silicon. In other words, the depression will extend to a depth which is defined (dictated) by the size of the opening (506) and the nature of the silicon substrate (502). For example, with square openings 63.5 μm (2.5 mils) per side, the depth of the depression will be approximately 50.8 μm (2 mils). Ultimately, these depressions 508 will become contact features integrally formed upon the resulting contact tip structure to be formed on the silicon substrate. This is preferably a photolithographic process, so that the size and spacing of the openings (506) and features (508) will be extremely precise, to tolerances of microns (10^{-6} meters).

[0089] Next, as illustrated in Figure 5C, the masking material 504 is removed, and a new masking layer 514 (compare 504), such as photoresist, is applied to the sur-

face of the silicon substrate 502 and is patterned to have a plurality (one of many shown) of openings 516 (compare 506) extending to the surface of the silicon substrate 502. The openings 516 are larger than the openings 506, and are aligned therewith. (Each opening 516 is over a depression 508.) An exemplary opening 516 is a rectangle suitably measuring approximately 178 μm (7 mils) (across the page, as shown) by 0.2 - 0.76 mm (8-30 mils) (into the page, as shown) Ultimately, these openings depressions 516 will be filled with conductive material forming the body of the contact tip structures being pre-fabricated on the sacrificial substrate 502. This is also preferably a photolithographic process, but the size and spacing of these openings 516 need not be as precise as previous openings 506, and tolerances on the order of up to 25.4 μm (1 mil (0.001 inch)) are generally acceptable.

[0090] Next, as illustrated by Figure 5C, a plurality (one of many shown) of multilayer contact tip structures 520 (compare 220, 420) is built up within the openings 516, each of which has a pyramid-shaped feature 530 extending from a surface thereof. In this example, the multilayer buildup is suitably:

- first deposit (apply) a release mechanism 522 such as has been described hereinabove (e.g., a multilayer buildup of lead/tungsten/lead);
- then deposit a relatively thin layer 524 of rhodium or tungsten (or ruthenium, or iridium, or hard nickel or cobalt or their alloys, or tungsten carbide), such as (0.1 - 1.0 mils thick) 2.54-25.4 μm ;
- then deposit a relatively thick layer 526 of nickel, cobalt or their alloys;
- finally deposit a relatively thin layer 528 of soft gold, which is readily brazed to.

[0091] In this manner, a plurality of elongate contact tip structures 520, each having a projecting pyramid-shaped contact feature 530 projecting from a surface thereof. It is this projecting contact feature that is intended to make the actual contact with a terminal (not shown) of an electronic component (not shown).

[0092] As shown in Figures 5D, 5E and 5F, the pyramid-shaped contact feature 530 is suitably polished (abraded) off, along the line 524, which will configure the pyramid-shaped feature as a truncated pyramid-shaped feature. The relatively small flat end shape (e.g., a square measuring a few tenths of a mil (1 mil = 25.4 μm) on a side), rather than a truly pointed end shape, will tend to be sufficiently "sharp" to make reliable pressure connections with terminals (not shown) of electronic components (not shown), and will tend to wear better than a truly pointed feature for making repeated (e.g., thousands of) pressure connections to a large number of electronic components, such as would be expected in an application of the tipped interconnection elements of the present invention for probing (e.g., silicon device wafers).

[0093] Another advantage of polishing off the point of

the contact feature 530 is that the second layer of the multilayer buildup can be exposed for making contact with a terminal (not shown) of an electronic component (not shown). For example, this layer can be of a material with superior electrical characteristics, such as rhodium. Or, it can be a material with superior wear characteristics, such as titanium-tungsten.

[0094] Figure 5E illustrates the elongate contact tip structure 520 of the present invention joined to an end of an elongate interconnection element 540 (compare 302). Figure 5F illustrates, however not in accordance with the present invention, the elongate contact tip structures 520 joined to a contact bump 322 of a membrane probe 324 (compare Figure 3C). In these exemplary applications, the contact tip structures 520 having projecting topological contact features 530 provide:

- a distinct metallurgy;
- a distinct contact topology (topography);
- tightly controlled positional tolerances; and
- if desired, a degree of pitch spreading.

[0095] Regarding effecting pitch spreading, it can be seen in Figure 5F that the contact tip structures can be arranged so that the spacing between the contact features 530 is greater (as shown) or lesser (not shown) than the spacing of the contact balls 322.

[0096] Generally, in use, the "tipped" interconnection element is mounted to a first electronic component, and the apex (top, as viewed in Figures 5E and 5F) portion of the pyramid effects an electrical connection to a terminal (not shown) of a second electronic component (not shown).

[0097] As mentioned above, by prefabricating contact tip structures (e.g., 520) with topological contact features (e.g., 530) on a surface thereof, it is possible to achieve extremely high positional precision for the pressure connection to be made, without requiring a comparable degree of precision in either the body portion of the contact tip structure or the interconnection element to which it is joined. By way of analogy, picture (in your mind) a golf course. A cup (hole) is precisely located on the green. A player is standing somewhere (anywhere) on the green. The cup, which is precisely located and of extremely precise dimensions (i.e., fractions of an inch), is analogous to the topological contact feature (e.g., 530). The green, which extends around the cup to coarse tolerances (i.e., feet or yards), is analogous to the body portion of the contact tip structure (e.g., 520). The player, who is standing somewhere (i.e., anywhere) on the green (the player's feet are the end of the interconnection element), is analogous to the interconnection element (e.g., 540) to which the contact tip structure is joined. In other words, the topological contact feature provides extreme precision to what can be relatively very sloppy positioning of the end of the interconnection element. Thus it can be seen that by providing each of a plurality of roughly positioned contact tip structures with a contact feature

which is precisely located with respect to topological contact features on other ones of the plurality of contact tip structures, precisely positioned connections can be made to terminals of electronic components.

AN ALTERNATE TIP TOPOLOGY

[0098] Figures 6A and 6B illustrate an embodiment of providing contact tip structures with topological contact features. In this example, a sacrificial substrate 602 has a masking layer 604 with a plurality (one of many shown) of openings 606. The surface of the sacrificial substrate (in this example, the sacrificial substrate is aluminum) is "prepared" for contact tip fabrication by urging a pointed tool down (into the page, as viewed) against the surface of the substrate, resulting in one or more, including three or more, preferably four (as illustrated) dimples (depressions) 608 being formed in the surface of the sacrificial substrate 602.

[0099] In subsequent processing steps wherein a contact tip structure is fabricated (such as has been described hereinabove), these depressions 608 will "mirror" themselves as one or more (four shown) "dimple" contact features 618 projecting from the main body of the resulting contact tip structure 620 (compare 102, 220, 420). As is known, three-legged chairs are more stable than four-legged chairs. Thus, although it might seem that having exactly three projecting features (618) would be preferred, by having four projecting features 618, preferably arranged evenly-spaced (like the corners of a square), one is virtually assured that when the contact tip structure 620 is urged against a corresponding flat-surfaced terminal (not shown) of an electronic component (not shown), the contact tip structure 620 will be permitted to "rock" back and forth (i.e., on two diagonally-opposed features 618) to pierce through oxidation and the like on the terminal, thereby effecting a reliable electrical pressure connection between the "tipped" interconnection element and the terminal. This is desirable for effecting pressure connections in certain applications.

AN ALTERNATE TIP METALLURGY

[0100] The desirability of fabricating multilayer tip structures and various tip metallurgies have been discussed hereinabove.

[0101] It is within the scope of this invention that the tip metallurgy is as follows: Starting with a silicon sacrificial substrate:

- Step 1. first deposit a layer of aluminum;
- Step 2. then deposit a layer of chrome;
- Step 3. then deposit a layer of copper; and
- Step 4. then deposit a layer of gold.

[0102] The resulting tip contact structure will have an aluminum contact surface (Step 1) and a gold surface (Step 4) for facilitating brazing (or the like) to an intercon-

nection element. The aluminum contact surface is ideal for making a pressure connection to an LCD panel, preferably a socketable connection using external instrumentalities (e.g., spring clips and the like) to hold the electronic component having the interconnection elements with the aforementioned tip structures to the LCD panel.

[0103] As an aid to visualizing the multilayer contact tip structure of this or any other embodiment described herein, attention is directed to the illustration of **Figures 2A and 4A**.

ELONGATE CONTACT TIP STRUCTURES

[0104] It has been described hereinabove how sacrificial substrates can be employed to:

- (a) prefabricate contact tip structures for subsequent attachment (joining) to tips (ends) of elongate interconnection elements (such as, but not limited to, composite interconnection elements), as well as to other types of interconnection elements (such as bump elements of membrane probes); and
- (b) prefabricate contact tip structures upon which interconnection elements can directly be fabricated for subsequent mounting as "tipped" interconnection elements to terminals of electronic components.

[0105] It will now be described, although not forming part of the present invention, how the contact tip structures themselves can function as interconnection elements, without requiring that they be joined to other existing interconnection elements. As will be described in greater detail hereinbelow, these contact tip structures which, in and of themselves, can function as spring contact elements, are generally elongate, and will still be referred to as "contact tip structures".

[0106] **Figures 7A-7F** illustrate a technique 700 for fabricating contact tip structures which are elongate and which, in use, will function as cantilever (plated cantilevered beam) spring contact elements, and mounting same to terminals of electronic components. These techniques are particularly well suited to ultimately mounting spring contact elements to electronic components such as semiconductor devices, space transformer substrates of probe card assemblies, and the like.

[0107] **Figure 7A** illustrates a sacrificial substrate 702 such as a silicon wafer, into a surface of which a plurality (one of many shown) trenches 704 are etched. The trenches 704 are illustrative of any surface texture 'template' for the contact tip structures which will be fabricated on the sacrificial substrate 702. (Compare the topological contact features described hereinabove.) The layout (spacing and arrangement) of the trenches 704 can be derived from (replicate; i.e., "mirror") the bond pad layout of a semiconductor die (not shown) which is ultimately (in use) intended to be contacted (e.g., probed). For example, the trenches 704 can be arranged in a row, single file, down the center of the sacrificial substrate. Many

memory chips, for example, are fabricated with a central row of bond pads.

[0108] **Figure 7B** illustrates that a hard "field" layer 706 has been deposited upon the surface of the sacrificial substrate 702, including into the trenches 704. Another layer 708, such as of a plateable material, can optionally be deposited over the field layer 706, if the field layer is of a material which is not amenable to plating such as tungsten-silicide, tungsten, or diamond. (If, as will be evident from the discussion hereinbelow, the layer 706 is difficult to remove, it may be applied by selective deposition (e.g., patterning through a mask), to avoid such removal.)

[0109] In a next step, illustrated by **Figure 7C**, a masking material 710, such as photoresist, is applied to define a plurality of openings for the fabrication of plated cantilever tip structures. The openings in the masking layer 710 extend to over the trenches 704. Next, a relatively thick (e.g., 1-3 mils) layer 712 of a spring alloy material (such as nickel and its alloys) is optionally deposited (such as by plating), over which a layer 714 of material is deposited which is amenable to brazing or soldering, in the event that the spring alloy is not easy to bond, solder or braze to. The spring alloy layer 712 is deposited by any suitable means such as plating, sputtering or CVD.

[0110] Next, as illustrated by **Figures 7D and 7E**, the masking material 710 is stripped (removed), along with that portion of the layers (706 and 708) which underlies the masking material 710, resulting in a plurality (one of many shown) of elongate contact tip structures 720 having been fabricated upon the sacrificial substrate 702. Each elongate contact tip structure 720 has an inner end portion 722 (directly over a corresponding one of the trenches 704), an outer end portion 724, and an intermediate portion 726 between the inner and outer end portions 722 and 724.

[0111] As is best viewed in **Figure 7E**, the cantilever tip structures 720 may be staggered (oriented left-right-left-right), so that although their inner end portions 722 are all aligned in a row (corresponding, e.g., to a central row of bond pads on a semiconductor device), with their outer end portions 724 oriented opposite one another. In this manner, the spacing between the outer end portions 724 of the contact tip structures 720 is at a greater (coarser) pitch (spacing) than the inner end portions 722.

[0112] Another feature of the cantilever tip structure 720 of the present invention is that the intermediate portion 726 can be tapered, as best viewed in **Figure 7E**, from narrowest at the inner (contact) end portion 722 to widest at the outer (base) end portion 724. This feature provides for controllable, determinate amount of deflection of the inner end portion 722 when the outer end portion 724 is rigidly mounted to a terminal of an electronic component such as a space transformer of a probe card assembly or a bond pad of a semiconductor device. Generally, deflection will be localized at or near the inner (contact) ends of the contact tip structures.

[0113] Figure 7F illustrates the mounting of the cantilever tip structures 720 fabricated according to the technique 700 of Figures 7A-7E to rigid "pedestals" 730 extending (e.g., free-standing) from corresponding terminals (one of many shown) 732 of an electronic component 734. Generally, the function of the pedestal 730 is simply to elevate the contact tip structure 720 in the z-axis, above the surface of the component 734, so that there is room for the contact end 722 to deflect (downwards, as viewed) when making a pressure connection to a terminal (not shown) of an electronic component (not shown). The pedestal (730) itself may be resilient, in which case the elongate contact tip structure (720) may or may not also be resilient, as desired for a specific application (use).

[0114] As illustrated, the pre-fabricated elongate tip structures 720 are mounted by their outer (base) end portions 724 to the ends (top, as shown) of the pedestals 730, in any suitable manner such as by brazing or soldering. Here, another advantage of the outer end portions being the widest portion of the cantilever tip structure 720 is evident, the large outer end portion of the elongate contact tip structure providing a relatively large surface area for performing such soldering or brazing, which is shown by the fillet structure 736, affording the opportunity to securely join the outer (base) end of the elongate contact structure to the pedestal.

[0115] The pedestal 730 can be any free-standing interconnection element including, but not limited to, composite interconnection elements, and specifically including contact bumps of probe membranes (in which case the electronic component 734 would be a probe membrane) and tungsten needles of conventional probe cards.

[0116] As best viewed in Figure 7F, the contact end portion (722) of the elongate contact tip structure (720) is provided with a raised feature 740 which, in use, effects the actual pressure connection to the terminal (not shown) of the electronic component (not shown). The shape and size of this feature 740 is controlled by the shape and size of the trench 704 (see Figure 7A).

[0117] In any cantilever beam arrangement, it is preferred that a one end of the cantilever be "fixed" and the other end "movable". In this manner, bending moments are readily calculated. Hence, it is evident that the pedestal (730) is preferably as rigid as possible. In the case of the elongate contact structure (720) being joined to a contact bump on a membrane probe, much resilience and/or compliance will be provided by the membrane (734), per se. In certain applications, it is desirable that the pedestal (730) would be implemented as a "composite interconnection element" (refer to the aforementioned PCT/US95/14909) which will contribute to the overall deflection of the contact ends of the elongate contact tip structures in response to pressure connections being made thereto.

EFFECTING PITCH-SPREADING WITH THE CONTACT TIP STRUCTURES

[0118] In the previous example (see Figure 7E), the contact tip structures (720) are arranged to have alternating orientations (left-right-left-right) so that their inner (contact) ends are at a first pitch and their outer (base) ends are at a second pitch which is greater (coarser) than the first pitch. A "pitch-spreading" effect can be achieved by fabricating the contact tip structures so as to have alternating lengths.

[0119] Figure 8 illustrates another technique 800 for effecting pitch-spreading with the contact tip structures (as opposed to, or in addition to, pitch-spreading which may be effected by a space transformer to which the contact tip structures are mounted).

[0120] In this example 800, a plurality (five of many shown) of elongate contact tip structures 820a..820e (collectively referred to as "820", compare 720) have been formed on a sacrificial substrate 802 (compare 702). Each contact tip structure 820 has an inner (contact) end 822 (822a..822e) and an outer (base) end 824 (824a..824e). In this figure, it can be observed that the inner ends 822 are aligned along a line labelled "R", and that the contact tip structures 820 are all disposed (oriented, extend) in the same direction (to the right, as viewed in the figure).

[0121] According to the invention, the elongate contact tip structures 820 have different lengths than one another and are arranged in an alternating manner such as long-short-long-short-long, so that their outer (base) ends 824a..824e have a greater pitch than their inner (contact) ends 822a..822e.

[0122] In use, the elongate contact tip structures 820 are readily mounted by their base ends 824 to terminals of an electronic component, in any suitable manner described hereinabove.

ANOTHER ELONGATE CONTACT TIP STRUCTURE

[0123] It has been described, hereinabove, how elongate cantilever contact tip structures (e.g., 720, 820) can be fabricated on sacrificial substrates using conventional semiconductor fabricating processes (including micromachining) such as masking, etching and plating, and how the resulting elongate cantilever contact tip structures can be provided with nonplanar (out-of-plane) "raised" features (e.g., 740). In other words, as will be evident, the shape of the resulting elongate cantilever contact tip structure can readily be controlled in all three (x,y,z) axes.

[0124] Figures 9A-9E illustrate alternate embodiments for elongate cantilever contact tip structures

[0125] Figures 9A and 9B illustrate an elongate contact tip structure (spring contact element) 900 that is suitable for attachment as a free-standing structure to an electronic component.

[0126] The structure 900 is elongate, has two ends 902

and 904, and has an overall longitudinal length of "L" between the two ends. By way of example, the length "L" is in the range of 0.25 - 25.4 mm (10-1000 mils), such as 1-12.7 mm (4-500 mils) or 1-6.35 mm (40-250 mils), preferably 1.5-2.5 mm (60-100 mils). As will become apparent from the discussion that follows, in use the structure has an "effective" length of "L1", which is less than "L", which is the length over which the structure 900 can flex in response to a force applied thereto.

[0127] The end 902 is a "base" whereat the contact element 900 will be mounted to an electronic component (not shown). The end 904 is a "free-end" (tip) which will effect a pressure connection with another electronic component (e.g., a device-under-test, not shown).

[0128] The structure 900 has an overall height of "H". By way of example, the height "H" is in the range of 0.1-1 mm (4-40 mils) preferably 127-305 μm (5-12 mils, (1 mil = 0.001 inches)).

[0129] As best viewed in Figure 9A, the structure 900 is "stepped". The base portion 902 is at a first height, the tip 904 is at another height, and a middle (central) portion 906 is at a third height which is between the first and second heights. Therefore, the structure 900 has two "standoff" heights, labelled "d1" and "d2" in the figure. In other words, the spring contact element 900 has two "steps", a step up from the contact end 904 to the central body portion 906, and a further step up from the central body portion 906 to the base end 902.

[0130] In use, the standoff height "d1", which is the "vertical" (as viewed in Figure 9A) distance between the contact end 904 and the central portion 906, performs the function of preventing bumping of the structure with the surface the electronic component (not shown) when deflecting in response to making a pressure connection with a terminal (not shown) of the electronic component (not shown).

[0131] In use, the standoff height "d2", which is the "vertical" (as viewed in Figure 9A) distance between the base end 902 and the central portion 906, performs the function of allowing the beam to bend through the desired overtravel, without contacting the surface of the substrate (including an electronic component) to which the elongate contact structure 900 is mounted.

[0132] By way of example, the dimensions for the standoff heights "d1" and "d2" are:

- "d1" is in the range of 76-381 μm (3-15 mils), preferably approximately $178 \pm 25 \mu\text{m}$ (7 mils + 1 mil); and

- "d2" is in the range of 0-381 μm (0-15 mils), preferably approximately $178 \pm 25 \mu\text{m}$ (7 mils + 1 mil). In the case of "d2" being 0 mil, the structure would be substantially planar (without the illustrated step) between the central portion 906 and the base portion 902.

[0133] As best viewed in Figure 9B, the structure 900 is may be provided with a distinct "joining feature" 910 at

its base end 902. The joining feature may be a tab or, optionally a stud, which is used to facilitate brazing the probe structure to a substrate (e.g., a space transformer or a semiconductor device) during assembly therewith.

Alternatively, the component or substrate to which the structure 900 is mounted may be provided with a stud (pedestal, compare 730) or the like to which the base portion 902 is mounted.

[0134] In use, the structure 900 is intended to function as a cantilever beam, and is preferably provided with at least one taper angle, labelled " α " in Figure 9B. By way of example, the width "w1" of the structure 900 at its base end 902 is in the range of 76 - 508 μm (3-20 mils), preferably 203 - 305 μm (8-12 mils), and the width "w2" of the structure 900 at its tip end 904 in the range of 25 - 254 μm (1-10 mils), preferably 51 - 203 μm (2-8 mils), and the taper angle " α " is preferably in the range of 2-6 degrees. The narrowing of (taper) the structure 900, from its base 902 to its tip 904, permits controlled flexure and more even stress distribution (versus concentration) of the structure 900 when its base 902 is secured (immovable) and a force is applied at its tip (904). The width of the structure (hence, the taper angle " α ") is readily controlled employing well-known lithographic techniques.

[0135] The tip end 904 of the structure 900 is preferably provided with a topological feature 908, for example in the geometric form of a pyramid, to aid in effecting pressure connection to a terminal of an electronic component (not shown).

[0136] As illustrated in Figures 9A and 9B, the spring contact element 900 is three-dimensional, extending in the x- y- and z-axes. Its length "L" is along the y-axis, its widths ("w1" and "w2") are along the x-axis, and its thicknesses ("t1" and "t2") and height ("H") are along the z-axis. When the spring contact element 900 is mounted to an electronic component, it will be mounted thereto so that the length and width of the spring contact element are parallel to the surface of the electronic component, and its height is normal to the surface of the electronic component.

[0137] Figure 9C illustrates a spring contact structure 950 similar in most respects to the structure 900 of Figures 9A and 9B. The structure is elongate, has a base end 952 (compare 902) and a contact end 954 (compare 904), and a topological feature 958 (compare 908) disposed at contact end 954. The principal difference being illustrated in Figure 9C is that the structure 950 can be provided with a second, z-axis, taper angle " β ".

[0138] For example, as best viewed in Figure 9C, the thickness "t1" of the structure 950 at its base end 952 is in the range of 25-254 μm (1-10 mils); preferably 51-127 μm (2-5 mils), and the thickness "t2" of the structure 950 at its contact end 954 in the range of 25-254 μm (1-10 mils) preferably 25-127 μm (1-5 mils) and the taper angle " β " is preferably in the range of 2-6 degrees.

[0139] The angle " β " (Figure 9C) may be created using various methods for controlling the thickness distribution. For example, if the structure 950 is formed by plating, a

suitable plating shield can be incorporated into the bath. If the structure 950 is formed other than by plating, appropriate known processes for controlling the spatial distribution of thickness of the resulting structure would be employed. For example, sandblasting or electro-discharge machining (EDM) the structure 950.

[0140] Thus, an elongate contact structure can be formed which has a composite (dual) taper from its base end (902, 952) to its contact end (904, 954). It may have a taper angle " α " which will be parallel to the x-y plane of the substrate or component to which the elongate contact structure is mounted. And it may have a taper angle " β " which represents a narrowing of the structure's thickness (z-axis). Both tapers represent a diminishing of the structure's (900, 950) cross-section from larger at its base end (902, 950) to smaller at its contact end (904, 954).

[0141] It is within the scope of this invention that the structure is not tapered in width, in which case the taper angle " α " would be ZERO. It is also within the scope of this invention that the taper angle " α " is greater than 2-6 degrees, for example as much as **30 degrees**. It is within the scope of this invention that the structure is not tapered in thickness, in which case the taper angle " β " would be ZERO. It is also within the scope of this invention that the taper angle " β " is greater than **2-6 degrees**, for example as much as **30 degrees**. It is within the scope of this invention that the structure is tapered only in thickness and not in width, or only in width and not in thickness.

[0142] The contact structures 900 and 950 are principally, preferably entirely, metallic, and may be formed (fabricated) as multilayer structures, as has been described hereinabove.

[0143] Figure 9D shows an enlarged view of the contact end 954 of the contact structure 950 (equally applicable to the contact ends of other contact structures illustrated herein). In this enlarged view it can be seen that the contact feature 954 is suitably quite prominent, projecting a distance " $d3$ ", in the range of 6.35-127 μm (**0.25-5 mils**), preferably 76 μm (**3 mils**) from the bottom (as viewed) surface of the contact end of the spring contact element, and is suitably in the geometric shape of a pyramid, wedge, a hemisphere, or the like.

[0144] The resulting spring contact element has an overall height " H " which is the sum of " $d1$ ", " $d2$ " (and " $d3$ ") plus the thickness of the central body portion.

[0145] There has thus been described a exemplary spring contact element suitable for effecting connections between two electronic components, typically being mounted by its base end to a one of the two electronic components and effecting a pressure connection with its contact end to an other of the two electronic components, having the following dimensions (in mils, unless otherwise specified):

| dimension | range | preferred |
|-----------|---------|-----------|
| L | 10-1000 | 60-100 |
| H | 4-40 | 5-12 |

Table continued

| dimension | range | preferred |
|-----------|--------|-----------|
| d1 | 3-15 | 7 \pm 1 |
| d2 | 0-15 | 7 \pm 1 |
| d3 | 0.25-5 | 3 |
| w1 | 3-20 | 8-12 |
| w2 | 1-10 | 2-8 |
| t1 | 1-10 | 2-5 |
| t2 | 1-10 | 1-5 |
| α | 0-30° | 2-6° |
| β | 0-30° | 2-6° |

(Note : 1 mil = 25.4 μm)

from which the following general relationships are evident:

- "L" is approximately at least 5 times "H";
- "d1" is a small fraction of "H", such as between one-fifth and one-half the size of "H";
- "w2" is approximately one-half the size of "w1", and is a small fraction of "H", such as between one-tenth and one-half the size of "H"; and
- "t2" is approximately one-half the size of "t1".

[0146] Figure 9E illustrates an alternate embodiment of the invention wherein discrete contact tip structures 972 (compare 220) can be joined to the contact ends 974 of elongate contact tip structures 970 (compare 900, 950), in lieu of providing the contact ends with integrally-formed raised contact features (908, 958). This provides the possibility of the contact tip structure 968 having a different metallurgy, than the elongate contact tip structures (spring contact elements) 970. For example, the metallurgy of the spring contact element 970 is suitably targeted at its mechanical (e.g., resilient, spring) characteristics and its general capability to conduct electricity, while the metallurgy of a contact tip structure 972 mounted thereto is appropriately targeted to making superior electrical connection with a terminal (not shown) of an electronic component (not shown) being contacted and, if needed, can have superior wear-resistance.

MATERIALS AND PROCESSES

[0147] Suitable materials for the one or more layers of the contact tip structures described herein include, but are not limited to:

- nickel, and its alloys;
- copper, cobalt, iron, and their alloys;
- gold (especially hard gold) and silver, both of which exhibit excellent current-carrying capabilities and good contact resistance characteristics;
- elements of the platinum group;
- noble metals;
- semi-noble metals and their alloys, particularly ele-

ments of the palladium group and their alloys; and tungsten, molybdenum and other refractory metals and their alloys.

[0148] In cases where a solder-like finish is desired, tin, lead, bismuth, indium and their alloys can also be used.

[0149] Suitable processes for depositing these materials (e.g., into openings in a masking layer on a sacrificial substrate) include, but are not limited to: various processes involving deposition of materials out of aqueous solutions; electrolytic plating; electroless plating; chemical vapor deposition (CVD); physical vapor deposition (PVD); processes causing the deposition of materials through induced disintegration of liquid or solid precursors; and the like, all of these techniques for depositing materials being generally well known. Electroplating is a generally preferred technique.

TAILORING (UNIFORMIZING) "K"

[0150] A plurality of elongate contact tip structures having different lengths (all other parameters such as materials and cross-section being equal) will exhibit different resistance to contact forces applied at their free (contact) ends. It is generally desirable that the spring constants "K" for all of the elongate contact tip structures mounted to a given electronic component be uniform.

[0151] Figures 10A-10D illustrate elongate contact tip structures (1000, 1020, 1040, 1060) mounted to electronic components (1010, 1030, 1050, 1070, respectively), and techniques for tailoring the resistances "K" of a plurality of otherwise non-uniform elongate contact tip structures to be uniform, and correspond to Figures 7A-7D of the aforementioned U.S. Provisional Patent Application No. 60/034,053 filed 12/31/96.

[0152] The elongate contact tip elements (1000, 1020, 1040, 1060) are similar to any of the elongate contact tip structures described hereinabove, and have a base end (1002, 1022, 1042, 1062) offset in a one direction from a central body portion (1006, 1026, 1046, 1066, respectively) and a tip portion (1004, 1024, 1044, 1064) offset in an opposite direction from the central body portion. Compare the elongate contact tip structures 900 and 950 of Figures 9A and 9C, respectively.

[0153] Figure 10A illustrates a first technique for tailoring spring constant. In this example, a spring contact element 1000 (compare any of the elongate contact tip structures described hereinabove) is mounted by its base end 1002 to a terminal of an electronic component 1010. A trench 1012 is formed in the surface of the electronic component 1010 and extends from under the contact end 1004 of the spring contact structure 1000, along the body portion 1006 thereof, towards the base end 1002 of the spring contact element 1000 to a position (point) "P" which is located a prescribed, fixed distance, such as 1.5 mm (60 mils) from the contact end 1004. When a force is applied downwards to the contact end 1004, it is in-

tended that the spring contact element 1000 will bend (deflect) until the body portion 1006 contacts the edge of the trench 1012 (i.e., the surface of the component 1010) at the point "P", whereupon only the outermost portion (from the point "P" to the end 804) of the spring contact element 1000 is permitted to further deflect. The outermost portion of the spring contact element has an 'effective' controlled length of "L1", which can readily be made the same for any number of spring contact elements (1000) having an overall length "L" which is greater than "L1". In this manner, the reaction ("K") to applied contact forces can be made uniform among spring contact elements of various lengths (so long as the point "P" falls somewhere within the central body portion of the spring contact element).

[0154] Figure 10B illustrates another technique for tailoring spring constant. In this example, a spring contact element 1020 is mounted by its base end 1022 to an electronic component 1030 (compare 1010). A structure 1032 (compare 1012) is formed on the surface of the electronic component 1030 at a location between the base end 1022 of the spring contact structure 820, between the surface of the electronic component 1030 and the central body portion 1026 (compare 1006) of the spring contact structure 1020 and extends along the body portion 1026 (compare 1006) thereof, towards the contact end 1024 (compare 1004) of the spring contact element 1020 to a position (point) "P" which is located a prescribed, fixed distance, such as the aforementioned (with respect to Figure 10A) prescribed distance, from the contact end 1024. The structure 1032 is suitably a bead of any hard material, such as glass or a pre-cut ceramic ring, disposed on the surface of the electronic component 1030. When a force is applied downwards to the contact end 1024, only the outermost portion (from the point "P" to the end 1024) of the spring contact element 1020 is permitted to deflect. As in the previous embodiment (1000), in this manner the reactions to applied contact forces can be made uniform among spring contact elements of various lengths.

[0155] Figure 10C illustrates yet another technique for tailoring spring constant. In this example, a spring contact element 1040 (compare 1000 and 1020) is mounted by its base end 1042 to an electronic component 1050. An encapsulating structure 1052 is formed on the surface of the electronic component 1050 in a manner similar to the structure 1032 of the previous embodiment. However, in this case, the structure 1052 fully encapsulates the base end 1042 of the spring contact structure 1040 and extends along the body portion 1046 thereof, towards the contact end 1044 thereof, to a position (point) "P" which is located a prescribed, fixed distance, such as the aforementioned (with respect to Figure 10B) prescribed distance, from the contact end 1044. The outermost portion of the spring contact element 1040 has an 'effective' length of "L1". As in the previous embodiments, when a force is applied downwards to the contact end 1044, only the outermost portion (from the point "P" to the end 1044)

of the spring contact element 1044 is permitted to deflect. As in the previous embodiments, the reactions to applied contact forces can be made uniform among spring contact elements of various lengths.

[0156] Figure 10D illustrates yet another technique for tailoring spring constant. In this example, a spring contact element 1060 (compare 1000, 1020, 1040) is mounted by its base end 1062 to an electronic component 1080 (compare 1050). In this example, the body portion 1066 is formed with a "kink" 1072 at a position (point) "P" which is located a prescribed, fixed distance, such as the aforementioned (with respect to Figure 8C) prescribed distance, from the contact end 1064. The outermost portion of the spring contact element 1060 thus has an 'effective' length of "L1". As in the previous embodiments, when a force is applied downwards to the contact end 1064, only the outermost portion (from the point "P" to the end 1064) of the spring contact element 1060 is permitted to deflect. (The kink 1072 can be sized and shaped so that the entire contact structure 1060 deflects slightly before the kink 1072 contacts the surface of the component 1070, after which only the outermost portion of the spring element 1060 will continue to deflect.) As in the previous embodiments, the reactions to applied contact forces can be made uniform among spring contact elements of various lengths.

[0157] Other techniques can be employed to "uniformize" the spring constants among contact elements having different overall lengths ("L"). For example, their widths and or "α" taper can specifically be made to be different from one another to achieve this desired result.

THREE-DIMENSIONAL ELONGATE CONTACT TIP STRUCTURES

[0158] There have been described hereinabove a number of elongate contact tip structures which are suitable to be mounted directly to, or fabricated upon, terminals of electronic components, and which are capable of extending "three-dimensionally" from the electronic component so that contact ends thereof are positioned to make pressure connections with terminals of another electronic component.

[0159] Figures 11A and 11B illustrate another embodiment of elongate contact tip structures which are suited to function, in and of themselves, as spring contact elements.

[0160] Figure 11A illustrates a spring contact element 1100 that has been fabricated according to the techniques set forth hereinabove, with the exception (noticeable difference) that the central body portion 1106 (compare 906) of the contact element is not straight. Although it may still lay in a plane (e.g., the x-y plane), it is illustrated as "jogging" along the x-axis while traversing the y-axis, in which case the base end 1102 (compare 902) will have a different x-coordinate than the contact end 1104 (compare 904) or the contact feature 1108 (compare 908) disposed at the contact end 1104.

[0161] Figure 11B illustrates another spring contact element 1150 that is similar in many respects to the spring contact element 1100 of Figure 11A, with the exception that there is a z-axis step between the central body portion 1156 (compare 1106) and the base portion 1152 (compare 1102) in addition to the step between the central portion 1156 and the contact end portion 1154 (compare 1104). The spring contact element 1150 is illustrated with a contact feature 1158 (compare 1108) at its contact end 1154.

[0162] Variations are for example, the resulting elongate contact tip structures and spring contact elements may be heat-treated to enhance their mechanical characteristics, either while they are resident upon the sacrificial substrate or after they are mounted to another substrate or an electronic component. Also, any heat incident to joining the contact tip structures to interconnection elements or mounting (e.g., by brazing) the spring contact elements to a component can advantageously be employed to "heat treat" the material of the interconnection element or spring contact element, respectively.

Claims

1. Method of fabricating interconnection devices, said interconnection devices having ends, comprising:

pre-fabricating contact tip structures (520) on a sacrificial substrate (502), having a surface with a topological contact feature (530, 908) which, in use, enhances electrical pressure connections being made by the contact tip structures with corresponding terminals of an electronic component;

joining the contact tip structures (520) by mounting their ends to the ends of elongate interconnection elements (540) which are fabricated in a separate process; and

after joining the contact tip structures (520) to the ends of the interconnection elements (540), removing the sacrificial substrate (502), resulting in tipped interconnection devices having said pre-fabricated contact tip structures at their ends.

2. Method, according to claim 1, wherein:

the contact tip structures (520) are elongate.

3. Method, according to claim 1, wherein the contact tip structures each comprises a cantilever beam.

4. Method, according to claim 1, wherein:

the topological contact feature (908) is in the shape of a pyramid.

5. Method, according to claim 1, wherein:
the topological contact feature (530) is in the shape of a truncated pyramid. 5
6. Method, according to claim 1, wherein:
the topological contact feature (608) is in the shape of one or more dimples. 10
7. Method, according to claim 1, wherein:
the contact tip structures (520) are formed using lithographic processes on the sacrificial substrate (502). 15
8. Method, according to claim 1, further comprising:
fabricating the contact tip structures (520) on the sacrificial substrate (502) as elongate contact tip structures, each elongate contact tip structure having a one end and an other end. 20
9. Method, according to claim 8, further comprising:
fabricating the elongate contact tip structures so that their one ends are collinear. 25
10. Method, according to claim 8, wherein:
the elongate contact tip structures (720) are of alternating orientation. 30
11. Method, according to claim 8, wherein:
the elongate contact tip structures (820a-820e) are of alternating length. 35
12. Method, according to claim 1, wherein:
the sacrificial substrate (502) is removed by etching. 40
13. Method, according to claim 1, wherein:
the sacrificial substrate (502) is removed by heating. 45
14. Method, according to claim 1, wherein:
the contact tip structures (520) are formed by providing a masking layer (504) on the sacrificial substrate (502), forming openings (506, 516) in the masking layer, and depositing at least one layer (524) of a metallic material into the openings. 50
15. Method, according to claim 14, wherein:
- the metallic material is selected from the group consisting of:
nickel, and its alloys;
copper, cobalt, iron, and their alloys;
gold, hard gold and silver;
elements of the platinum group;
noble metals;
semi-noble metals and their alloys, particularly elements of the palladium group and their alloys;
tungsten, molybdenum and other refractory metals and their alloys; and
tin, lead, bismuth, indium and their alloys. 55
16. Method, according to claim 1, wherein:
the contact tip structures (720) are elongate and are tapered in a first direction from a one end to an opposite end thereof.
17. Method, according to claim 16, wherein:
the contact tip structures are tapered in another direction, orthogonal to the first direction from the one end to the opposite end thereof.
18. Method, according to claim 1, further comprising:
providing each of a plurality of contact tip structures (520) with a contact feature which is precisely located with respect to topological contact features on other ones of the plurality of contact tip structures.
19. Method of interconnecting two electronic components, comprising:
fabricating elongate interconnection elements (540) on one of two electronic components, fabricating contact tip structures (520) on a sacrificial substrate (502), wherein the contact tip structures comprise cantilever beams; thereafter joining the contact tip structures (520) to the elongate interconnection elements (540) and removing the sacrificial substrate (502); and urging the contact tip structures (520) against corresponding terminals on another of the two electronic components.
20. Method, according to claim 19, wherein:
the one of the two electronic components (254) is a semiconductor device.
21. Method, according to claim 20, wherein:
the semiconductor device is an ASIC.

22. Method, according to claim 20, wherein:
the semiconductor device is a microprocessor.
23. Method, according to claim 19, wherein:
the one of the two electronic components (254) is a component of a probe card assembly.
24. Method, according to claim 19, wherein:
the one of the two electronic components (254) is a space transformer of a probe card assembly.
25. Method, according to claim 19, wherein:
the other of the two electronic components is a semiconductor device.
26. Method, according to claim 19, wherein:
the other of the two electronic components is a semiconductor device resident on a semiconductor wafer.
27. Method, according to claim 26, wherein:
the semiconductor device is a memory device.
28. Method of forming a plurality of contact tip structures on a sacrificial substrate (702), comprising:
fabricating elongate interconnection elements (540) on an electronic component;
preparing a sacrificial substrate (502) by forming a release mechanism (522) on a surface thereof and defining a plurality of locations whereat the plurality of contact tip structures will be fabricated;
fabricating the plurality of contact tip structures (520) at the plurality of locations on the prepared sacrificial substrate (502), wherein the contact tip structures comprise cantilever beams; and thereafter joining the contact tip structures (520) to the ends of the elongate interconnection elements (540).
29. Method, according to claim 28, wherein:
the release mechanism is adapted in use to release the contact tip structures (520) from the sacrificial substrate (502) by a process selected from the group consisting of heat and chemical etching.
30. Method, according to claim 28, wherein:
the sacrificial substrate (502) is prepared with precisely located topological features within each of the plurality of locations.
31. Method, according to claim 28, wherein:
the contact tip structures (520) have multiple layers, a first layer of a material selected for its superior contact resistance, a final layer of a material selected for its joinability, and an intermediate layer of a material selected for its structural integrity.
32. Method, according to claim 28, wherein:
the sacrificial substrate is a silicon substrate; the silicon substrate is prepared by:
depositing a layer of aluminum on a surface of a silicon substrate;
depositing a layer of copper atop the aluminum layer;
depositing a layer of masking material atop the copper layer; and
processing the masking layer to have a plurality of openings at the plurality of locations, said openings extending through the masking layer to the underlying copper layer; and
the plurality of contact tip structures is fabricated on the prepared silicon substrate by:
depositing a layer of nickel within the openings onto the copper layer; and
depositing a layer of gold onto the nickel layer.
33. Method, according to claim 32, wherein:
the aluminum layer has a thickness of approximately 2,000 nm (20,000 Å);
the copper layer has a thickness of approximately 500 nm (5,000 Å);
the masking layer has a thickness of approximately 51 µm (2 mils); and
the nickel layer has a thickness of approximately 25.4 - 38 µm (1.0 - 1.5 mils).
34. Method, according to claim 32, further comprising:
prior to depositing the layer of aluminum, depositing a layer of titanium onto the surface of the silicon substrate.
35. Method, according to claim 32, further comprising:
prior to depositing the layer of nickel, depositing a layer of a noble metal onto the copper layer.

36. Method, according to claim 28, wherein:

the sacrificial substrate is aluminum;
the aluminum substrate is prepared by:

depositing a layer of masking material onto a surface of the aluminum substrate; and processing the masking layer to have a plurality of openings at the plurality of locations, said openings extending through the masking layer to the underlying aluminum substrate; and

the plurality of contact tip structures is fabricated on the prepared aluminum substrate by:

depositing a thin layer of hard gold onto the aluminum substrate within the openings; depositing a relatively thick layer of nickel onto the hard gold layer; and depositing a thin layer of soft gold onto the nickel layer.

37. Method, according to claim 36, wherein:

the hard gold layer has a thickness of approximately 2.54 μm (100 microinches); the nickel layer has a thickness of approximately 51 μm (2 mils); and the soft gold layer has a thickness of approximately 2.54 μm (100 microinches).

38. Method, according to claim 36, further comprising:

prior to depositing the nickel layer, depositing a very thin copper strike onto the hard gold layer.

39. Method, according to claim 36, further comprising:

providing the aluminum substrate with a backing sheet.

40. Method, according to claim 28, wherein:

the sacrificial substrate is a silicon substrate; and the silicon substrate is prepared by:

etching pits into the silicon substrate at specific locations whereat it is desired to have topological features on the contact tip structures that will be fabricated; applying a masking layer and patterning the masking layer to have openings at locations whereat the contact tip structures will be fabricated.

41. Method, according to claim 28, wherein:

the release mechanism is a non-wettable material deposited onto the surface of the substrate, and a non-wetting material deposited onto the non-wettable material.

42. Method, according to claim 41, further comprising:

depositing a second layer of non-wettable material over the layer of non-wetting material.

43. Method, according to claim 42, further comprising:

depositing a second layer of non-wetting material over the second layer of non-wettable material.

44. Method, according to claim 43, further comprising:

depositing a barrier layer over the second layer of non-wetting material.

45. Method, according to claim 28, wherein:

the sacrificial substrate is a silicon substrate; the plurality of contact tip structures is fabricated on the prepared silicon substrate by:

depositing a layer of aluminum, then depositing a layer of chrome, then depositing a layer of copper, then depositing a layer of gold.

46. Contact tip structures adapted in use for joining to corresponding ends of elongate interconnection elements which are extending from terminals on a surface of a substrate, comprising:

a plurality of contact tip structures (520) fabricated and residing upon a sacrificial substrate (502) at predetermined positions on the sacrificial substrate;

wherein, in use, the sacrificial substrate (502) is separated from the contact tip structures (520) after the contact tip structures are joined to corresponding ends of elongate interconnection elements which are extending from a corresponding plurality of the terminals of the substrate, wherein the contact tip structures each comprises a cantilever beam.

47. Prefabricated contact tip structures adapted in use for making connections to corresponding ends of elongate interconnection elements which are extending from terminals of an electronic component, comprising:

a plurality of metallic contact tip structures formed upon a sacrificial substrate (502), said

contact tip structures adapted in use to be joined to corresponding ends of elongate interconnection elements which are extending from the terminals of the electronic component, wherein the contact tip structures (520) each comprises a cantilever beam, and wherein the contact tip structures are adapted to effect electrical connections between the electronic component and another electronic component having the sacrificial substrate removed.

48. Prefabricated contact tip structures, according to claim 47, wherein:

the metallic structures are multilayer metallic structures;
the sacrificial substrate is a sheet of metal;
the metal is aluminum;
the sacrificial substrate is a silicon wafer;
the sacrificial substrate is a material selected from the group consisting of aluminum, copper and silicon.

49. Prefabricated contact tip structures, according to claim 47, wherein:

the metallic structures are of one or more layers of a material selected from the group consisting of:

nickel, and its alloys;
copper, cobalt, iron, and their alloys;
gold (especially hard gold) and silver, both of which exhibit excellent current-carrying capabilities and good contact resistivity characteristics;
elements of the platinum group;
noble metals;
semi-noble metals and their alloys, particularly elements of the platinum group and their alloys;
tungsten, molybdenum and other refractory metals and their alloys; and
tin, lead, bismuth, indium and their alloys.

50. Prefabricated contact tip structures, according to claim 47, wherein:

each metallic structure has a topology on a surface thereof; and
the surface having a topology is that surface which, in use, effects a pressure connection to the terminals of the other electronic components.

51. Method, according to claim 1 or 19, further comprising providing a trench (1012) in the surface of the electronic component (1010) adjacent an elongate

portion of the contact tip structure (1000).

52. Method, according to claim 1 or 19, further comprising providing a structure (1032, 1052) between the surface of the electronic component (1030, 1050) and an elongate portion of the contact tip structure (1020, 1040).

53. Method according to claim 52, wherein said structure (1052) envelopes a portion (1042) of the contact tip structure (1040).

54. Method, according to claim 1 or 19, wherein an elongate portion of the contact tip structure comprises a kink (1072).

55. Method, according to claim 54, wherein the kink (1072) is disposed toward the surface of the electronic component (1070).

Patentansprüche

1. Verfahren zur Herstellung von Verbindungsvorrichtungen, wobei die Verbindungsvorrichtungen Enden haben, aufweisend:

Vorfertigen von Kontaktspitzenstrukturen (520) auf einem Opfersubstrat (502) mit einer Oberfläche mit einer topologischen Kontaktstruktur (530, 908), die bei der Verwendung elektrische Druckverbindungen verbessert, die durch die Kontaktspitzenstrukturen mit entsprechenden Anschlüssen eines elektronischen Bauteils hergestellt werden;
Verbinden der Kontaktspitzenstrukturen (520) durch Anbringen ihrer Enden an den Enden von länglichen Verbindungselementen (540), die in einem separaten Prozess hergestellt werden; und
Entfernen des Opfersubstrats (502) nach dem Verbinden der Kontaktspitzenstrukturen (520) mit den Enden der Verbindungselemente (540), was zu mit Spitzen versehenen Verbindungsvorrichtungen führt, die die vorgefertigten Kontaktspitzenstrukturen an ihren Enden aufweisen.

2. Verfahren nach Anspruch 1, wobei:

die Kontaktspitzenstrukturen (520) länglich sind.

3. Verfahren nach Anspruch 1, wobei die Kontaktspitzenstrukturen jeweils einen Auslegerbalken aufweisen.

4. Verfahren nach Anspruch 1, wobei:

- die topologische Kontaktstruktur (908) in Form einer Pyramide vorliegt.
5. Verfahren nach Anspruch 1, wobei:
- 5 die topologische Kontaktstruktur (530) in Form eines Pyramidenstumpfs vorliegt.
6. Verfahren nach Anspruch 1, wobei:
- 10 die topologische Kontaktstruktur (608) in Form von einer oder mehreren Vertiefungen vorliegt.
7. Verfahren nach Anspruch 1, wobei:
- 15 die Kontaktspitzenstrukturen (520) unter Verwendung von lithographischen Prozessen auf dem Opfersubstrat (502) ausgebildet werden.
8. Verfahren nach Anspruch 1, welches ferner aufweist:
- 20 Herstellen der Kontaktspitzenstrukturen (520) auf dem Opfersubstrat (502) als längliche Kontaktspitzenstrukturen,
- 25 wobei jede längliche Kontaktspitzenstruktur ein Ende und ein weiteres Ende aufweist.
9. Verfahren nach Anspruch 8, welches ferner aufweist:
- 30 Herstellen der länglichen Kontaktspitzenstrukturen derart, dass ihre einen Enden kollinear sind.
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10. Verfahren nach Anspruch 8, wobei:
- 40 die länglichen Kontaktspitzenstrukturen (720) eine abwechselnde Orientierung aufweisen.
11. Verfahren nach Anspruch 8, wobei:
- 45 die länglichen Kontaktspitzenstrukturen (820a-820e) eine abwechselnde Länge aufweisen.
12. Verfahren nach Anspruch 1, wobei:
- 50 das Opfersubstrat (502) durch Ätzen entfernt wird.
13. Verfahren nach Anspruch 1, wobei:
- 55 das Opfersubstrat (502) durch Erwärmen entfernt wird.
14. Verfahren nach Anspruch 1, wobei:
- die Kontaktspitzenstrukturen (520) durch Vorsehen einer Maskierungsschicht (504) auf dem Opfersubstrat (502), Ausbilden von Öffnungen (506, 516) in der Maskierungsschicht und Abscheiden mindestens einer Schicht (524) aus einem Metallmaterial in den Öffnungen ausgebildet werden.
15. Verfahren nach Anspruch 14, wobei:
- das Metallmaterial aus der Gruppe ausgewählt wird, die aus folgendem besteht:
- Nickel und seinen Legierungen;
Kupfer, Kobalt, Eisen und ihren Legierungen;
Gold, hartem Gold und Silber;
Elementen der Platingruppe;
Edelmetallen;
Halbedelmetallen und ihren Legierungen, insbesondere Elementen der Palladiumgruppe und ihren Legierungen;
Wolfram, Molybdän und anderen schwer schmelzenden Metallen und ihren Legierungen; und
Zinn, Blei, Wismut, Indium und ihren Legierungen.
16. Verfahren nach Anspruch 1, wobei:
- die Kontaktspitzenstrukturen (720) länglich sind und in einer ersten Richtung von einem Ende zu einem entgegengesetzten Ende derselben verjüngt sind.
17. Verfahren nach Anspruch 16, wobei:
- die Kontaktspitzenstrukturen in einer anderen, Richtung, die zur ersten Richtung senkrecht ist, vom einen Ende zum entgegengesetzten Ende derselben verjüngt sind.
18. Verfahren nach Anspruch 1, welches ferner aufweist:
- Versehen von jeder einer Vielzahl von Kontaktspitzenstrukturen (520) mit einer Kontaktstruktur, die bezüglich der topologischen Kontaktstrukturen an anderen der Vielzahl von Kontaktspitzenstrukturen genau angeordnet wird.
19. Verfahren zum Verbinden von zwei elektronischen Bauteilen, aufweisend:
- Herstellen von länglichen Verbindungselementen (540) an einem von zwei elektronischen Bauteilen;
Herstellen von Kontaktspitzenstrukturen (520)

- auf einem Opfersubstrat (502), wobei die Kontaktspitzenstrukturen Auslegerbalken aufweisen;
anschließend Verbinden der Kontaktspitzenstrukturen (520) mit den länglichen Verbindungselementen (540) und Entfernen des Opfersubstrats (502); und
Drücken der Kontaktspitzenstrukturen (520) gegen entsprechende Anschlüsse an einem anderen der zwei elektronischen Bauteile. 5 10
20. Verfahren nach Anspruch 19, wobei:
das eine der zwei elektronischen Bauteile (254) ein Halbleiterbauelement ist. 15
21. Verfahren nach Anspruch 20, wobei:
das Halbleiterbauelement ein ASIC ist. 20
22. Verfahren nach Anspruch 20, wobei:
das Halbleiterbauelement ein Mikroprozessor ist. 25
23. Verfahren nach Anspruch 19, wobei:
das eine der zwei elektronischen Bauteile (254) eine Komponente einer Nadelkartenanordnung ist. 30
24. Verfahren nach Anspruch 19, wobei:
das eine der zwei elektronischen Bauteile (254) ein Raumtransformator einer Nadelkartenanordnung ist. 35
25. Verfahren nach Anspruch 19, wobei:
das andere der zwei elektronischen Bauteile ein Halbleiterbauelement ist. 40
26. Verfahren nach Anspruch 19, wobei:
das andere der zwei elektronischen Bauteile ein Halbleiterbauelement ist, das sich auf einem Halbleiterwafer befindet. 45
27. Verfahren nach Anspruch 26, wobei:
das Halbleiterbauelement ein Speicherbauelement ist. 50
28. Verfahren zum Ausbilden einer Vielzahl von Kontaktspitzenstrukturen auf einem Opfersubstrat (702), aufweisend:
Herstellen von länglichen Verbindungselemen- 55
- ten (540) auf einem elektronischen Bauteil;
Vorbereiten eines Opfersubstrats (502) durch Ausbilden eines Lösemechanismus (522) auf einer Oberfläche desselben und Festlegen einer Vielzahl von Stellen, an denen die Vielzahl von Kontaktspitzenstrukturen hergestellt werden;
Herstellen der Vielzahl von Kontaktspitzenstrukturen (520) an der Vielzahl von Stellen auf dem vorbereiteten Opfersubstrat (502), wobei die Kontaktspitzenstrukturen Auslegerbalken aufweisen; und
anschließend Verbinden der Kontaktspitzenstrukturen (520) mit den Enden der länglichen Verbindungselemente (540).
29. Verfahren nach Anspruch 28, wobei:
der Lösemechanismus bei der Verwendung dazu ausgelegt ist, die Kontaktspitzenstrukturen (520) vom Opfersubstrat (502) durch einen Prozess zu lösen, der aus der Gruppe ausgewählt wird, die aus Wärme und chemischem Ätzen besteht.
30. Verfahren nach Anspruch 28, wobei:
das Opfersubstrat (502) mit genau angeordneten topologischen Strukturen innerhalb von jeder der Vielzahl von Stellen vorbereitet wird.
31. Verfahren nach Anspruch 28, wobei:
die Kontaktspitzenstrukturen (520) mehrere Schichten aufweisen, eine erste Schicht aus einem Material, das wegen seines überlegenen Kontaktwiderstandes ausgewählt wird, eine Endschicht aus einem Material, das wegen seiner Verbindungsfähigkeit ausgewählt wird, und eine Zwischenschicht aus einem Material, das wegen seiner strukturellen Integrität ausgewählt wird.
32. Verfahren nach Anspruch 28, wobei:
das Opfersubstrat ein Siliziumsubstrat ist;
das Siliziumsubstrat vorbereitet wird durch:
Abscheiden einer Aluminiumschicht auf einer Oberfläche eines Siliziumsubstrats;
Abscheiden einer Kupferschicht auf der Aluminiumschicht;
Abscheiden einer Schicht aus Maskierungsmaterial auf der Kupferschicht; und
Bearbeiten der Maskierungsschicht derart, dass sie eine Vielzahl von Öffnungen an der Vielzahl von Stellen aufweist, wobei sich die Öffnungen durch die Maskierungsschicht hindurch zur darunterliegenden Kupfer-

- schicht erstrecken; und
- die Vielzahl von Kontaktspitzenstrukturen auf dem vorbereiteten Siliziumsubstrat hergestellt werden durch:
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- Abscheiden einer Nickelschicht innerhalb der Öffnungen auf der Kupferschicht; und Abscheiden einer Goldschicht auf der Nickelschicht.
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33. Verfahren nach Anspruch 32, wobei:
- die Aluminiumschicht eine Dicke von ungefähr 2000 nm (20000 Å) aufweist;
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- die Kupferschicht eine Dicke von ungefähr 500 nm (5000 Å) aufweist;
- die Maskierungsschicht eine Dicke von ungefähr 51 µm (2 mils) aufweist; und
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- die Nickelschicht eine Dicke von ungefähr 25,4 - 38 µm (1,0 - 1,5 mils) aufweist.
34. Verfahren nach Anspruch 32, welches ferner aufweist:
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- Abscheiden einer Titanschicht auf der Oberfläche des Siliziumsubstrats vor dem Abscheiden der Aluminiumschicht.
35. Verfahren nach Anspruch 32, welches ferner aufweist:
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- Abscheiden einer Schicht aus einem Edelmetall auf der Kupferschicht vor dem Abscheiden der Nickelschicht.
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36. Verfahren nach Anspruch 28, wobei:
- das Opfersubstrat Aluminium ist;
- das Aluminiumsubstrat vorbereitet wird durch:
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- Abscheiden einer Schicht aus Maskierungsmaterial auf einer Oberfläche des Aluminiumsubstrats; und
- 45
- Bearbeiten der Maskierungsschicht derart, dass sie eine Vielzahl von Öffnungen an der Vielzahl von Stellen aufweist, wobei sich die Öffnungen durch die Maskierungsschicht hindurch zum darunterliegenden Aluminiumsubstrat erstrecken; und
- 50
- die Vielzahl von Kontaktspitzenstrukturen auf dem vorbereiteten Aluminiumsubstrat hergestellt werden durch:
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- Abscheiden einer dünnen Schicht aus hartem Gold auf dem Aluminiumsubstrat innerhalb der Öffnungen;
- Abscheiden einer relativ dicken Nickelschicht auf der Schicht aus hartem Gold; und
- Abscheiden einer dünnen Schicht aus weichem Gold auf der Nickelschicht.
37. Verfahren nach Anspruch 36, wobei:
- die Schicht aus hartem Gold eine Dicke von ungefähr 2,54 µm (100 Mikroinch) aufweist;
- die Nickelschicht eine Dicke von ungefähr 51 µm (2 mils) aufweist; und
- die Schicht aus weichem Gold eine Dicke von ungefähr 2,54 µm (100 Mikroinch) aufweist.
38. Verfahren nach Anspruch 36, welches ferner aufweist:
- Abscheiden eines sehr dünnen Kupferdecküberzugs auf der Schicht aus hartem Gold vor dem Abscheiden der Nickelschicht.
39. Verfahren nach Anspruch 36, welches ferner aufweist:
- Versehen des Aluminiumsubstrats mit einer Unterlageschicht.
40. Verfahren nach Anspruch 28, wobei:
- das Opfersubstrat ein Siliziumsubstrat ist; und
- das Siliziumsubstrat vorbereitet wird durch:
- Ätzen von Vertiefungen in das Siliziumsubstrat an speziellen Stellen, an denen es erwünscht ist, dass topologische Strukturen an den Kontaktspitzenstrukturen, die hergestellt werden, vorhanden sind;
- Aufbringen einer Maskierungsschicht und Strukturieren der Maskierungsschicht derart, dass sie an Stellen Öffnungen aufweist, an denen die Kontaktspitzenstrukturen hergestellt werden.
41. Verfahren nach Anspruch 28, wobei:
- der Lösemechanismus ein nicht benetzbares Material, das auf der Oberfläche des Substrats abgeschieden wird, und ein nichtnetzendes Material, das auf dem nicht benetzbaren Material abgeschieden wird, ist.
42. Verfahren nach Anspruch 41, welches ferner aufweist:
- Abscheiden einer zweiten Schicht aus einem nicht benetzbaren Material über der Schicht aus nichtnetzendem Material.

43. Verfahren nach Anspruch 42, welches ferner aufweist:

Abscheiden einer zweiten Schicht aus nichtnetztemdem Material über der zweiten Schicht aus nicht benetzbarem Material. 5

44. Verfahren nach Anspruch 43, welches ferner aufweist:

Abscheiden einer Sperrschicht über der zweiten Schicht aus nichtnetztemdem Material. 10

45. Verfahren nach Anspruch 28, wobei:

das Opfersubstrat ein Siliziumsubstrat ist;
die Vielzahl von Kontaktspitzenstrukturen auf dem vorbereiteten Siliziumsubstrat hergestellt werden durch: 15

Abscheiden einer Aluminiumschicht, dann Abscheiden einer Chromschicht, dann Abscheiden einer Kupferschicht, dann Abscheiden einer Goldschicht. 20

46. Kontaktspitzenstrukturen, die bei der Verwendung zum Verbinden mit entsprechenden Enden von länglichen Verbindungselementen ausgelegt sind, die sich von Anschlüssen auf einer Oberfläche eines Substrats erstrecken, aufweisend: 25

eine Vielzahl von Kontaktspitzenstrukturen (520), die auf einem Opfersubstrat (502) an vorbestimmten Stellen auf diesem hergestellt sind und sich auf diesem befinden; 30

wobei das Opfersubstrat (502) bei der Verwendung von den Kontaktspitzenstrukturen (520) getrennt wird, nachdem die Kontaktspitzenstrukturen mit entsprechenden Enden von länglichen Verbindungselementen verbunden sind, die sich von einer entsprechenden Vielzahl der Anschlüsse des Substrats erstrecken, wobei die Kontaktspitzenstrukturen jeweils einen Auslegerbalken aufweisen. 40

47. Vorgefertigte Kontaktspitzenstrukturen, die bei der Verwendung dazu ausgelegt sind, Verbindungen mit entsprechenden Enden von länglichen Verbindungselementen herzustellen, die sich von Anschlüssen eines elektronischen Bauteils erstrecken, aufweisend: 45

eine Vielzahl von metallischen Kontaktspitzenstrukturen, die auf einem Opfersubstrat (502) ausgebildet sind, wobei die Kontaktspitzenstrukturen bei der Verwendung dazu ausgelegt sind, mit entsprechenden Enden von länglichen Verbindungselementen verbunden zu werden, 50

die sich von den Anschlüssen des elektronischen Bauteils erstrecken, wobei die Kontaktspitzenstrukturen (520) jeweils einen Auslegerbalken aufweisen, und wobei die Kontaktspitzenstrukturen dazu ausgelegt sind, elektrische Verbindungen zwischen dem elektronischen Bauteil und einem weiteren elektronischen Bauteil zu bewirken, wobei das Opfersubstrat entfernt wurde.

48. Vorgefertigte Kontaktspitzenstrukturen nach Anspruch 47, wobei:

die metallischen Strukturen mehrlagige metallische Strukturen sind;
das Opfersubstrat ein Metallplatte ist;
das Metall Aluminium ist;
das Opfersubstrat ein Siliziumwafer ist;
das Opfersubstrat ein Material ist, das aus der Gruppe ausgewählt ist, die aus Aluminium, Kupfer und Silizium besteht. 15

49. Vorgefertigte Kontaktspitzenstrukturen nach Anspruch 47, wobei:

die metallischen Strukturen eine oder mehrere Schichten aus einem Material sind, das aus der Gruppe ausgewählt ist, die aus folgendem besteht: 25

Nickel und seinen Legierungen;
Kupfer, Kobalt, Eisen und ihren Legierungen;
Gold (insbesondere hartem Gold) und Silber, die beide eine ausgezeichnete Strombelastbarkeit und gute Kontaktwiderstandseigenschaften aufweisen;
Elementen der Platingruppe;
Edelmetallen;
Halbedelmetallen und ihren Legierungen, insbesondere Elementen der Platingruppe und ihren Legierungen;
Wolfram, Molybdän und anderen schwer schmelzenden Metallen und ihren Legierungen; und
Zinn, Blei, Wismut, Indium und ihren Legierungen. 40

50. Vorgefertigte Kontaktspitzenstrukturen nach Anspruch 47, wobei:

jede metallische Struktur eine Topologie an einer Oberfläche derselben aufweist; und
die Oberfläche mit einer Topologie diejenige Oberfläche ist, die bei der Verwendung eine Druckverbindung mit den Anschlüssen der anderen elektronischen Bauteile bewirkt. 45

51. Verfahren nach Anspruch 1 oder 19, welches ferner das Vorsehen eines Grabens (1012) in der Oberfläche des elektronischen Bauteils (1010) benachbart zu einem länglichen Teil der Kontaktspitzenstruktur (1000) aufweist.
52. Verfahren nach Anspruch 1 oder 19, welches ferner das Vorsehen einer Struktur (1032, 1052) zwischen der Oberfläche des elektronischen Bauteils (1030, 1050) und einem länglichen Teil der Kontaktspitzenstruktur (1020, 1040) aufweist.
53. Verfahren nach Anspruch 52, wobei die Struktur (1052) einen Teil (1042) der Kontaktspitzenstruktur (1040) umhüllt.
54. Verfahren nach Anspruch 1 oder 19, wobei ein länglicher Teil der Kontaktspitzenstruktur einen Knick (1072) aufweist.
55. Verfahren nach Anspruch 54, wobei der Knick (1072) in Richtung der Oberfläche des elektronischen Bauteils (1070) angeordnet wird.

Revendications

1. Procédé de fabrication de dispositifs d'interconnexion, lesdits dispositifs d'interconnexion ayant des extrémités, comprenant :

la préfabrication de structures à pointes de contact (520) sur un substrat sacrificiel (502) ayant une surface dotée d'une caractéristique de contact topologique (530, 908) qui, en usage, améliore les connexions de pression électriques étant établies par les structures à pointes de contact avec des bornes correspondantes d'un composant électronique ;
le raccordement des structures à pointes de contact (520) par le montage de leurs extrémités aux extrémités des éléments d'interconnexion allongés (540) qui sont fabriqués dans un processus séparé ; et
après le raccordement des structures de pointes à contact (520) aux extrémités des éléments d'interconnexion (540), le retrait du substrat sacrificiel (502), résultant dans des dispositifs d'interconnexion à pointes ayant lesdites structures à pointes de contact préfabriquées à leurs extrémités.

2. Procédé, selon la revendication 1, dans lequel :

les structures à pointes de contact (520) sont allongées.

3. Procédé, selon la revendication 1, dans lequel les

structures à pointes de contact comprennent chacune un cantilever ou une poutre encastrée à une extrémité (poutre-console).

4. Procédé, selon la revendication 1, dans lequel :

la caractéristique de contact topologique (908) a la forme d'une pyramide.

5. Procédé, selon la revendication 1, dans lequel :

la caractéristique de contact topologique (530) a la forme d'une pyramide tronquée.

6. Procédé, selon la revendication 1, dans lequel :

la caractéristique de contact topologique (608) a la forme d'un ou de plusieurs crans d'arrêt ou d'une bosse.

7. Procédé, selon la revendication 1, dans lequel :

les structures à pointes de contact (520) sont formées en utilisant des processus lithographiques sur le substrat sacrificiel (502).

8. Procédé, selon la revendication 1, comprenant en outre :

la fabrication des structures à pointes de contact (520) sur le substrat sacrificiel (502) en tant que structures à pointes de contact allongées, chaque structure à pointes de contact allongée ayant une première extrémité et une autre extrémité.

9. Procédé selon la revendication 8, comprenant en outre :

la fabrication des structures à pointes de contact allongées de sorte que leurs premières extrémités soient colinéaires.

10. Procédé selon la revendication 8, dans lequel :

les structures à pointes de contact allongées (720) sont d'orientation alternative.

11. Procédé selon la revendication 8, dans lequel :

les structures à pointes de contact allongées (820a-820e) sont de longueur alternative.

12. Procédé selon la revendication 1, dans lequel :

le substrat sacrificiel (502) est retiré ou enlevé par attaque ou gravure chimique.

13. Procédé selon la revendication 1, dans lequel :

le substrat sacrificiel (502) est retiré ou enlevé par chauffage.

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14. Procédé selon la revendication 1, dans lequel :

les structures à pointes de contact (520) sont formées en fournissant une couche de masquage (504) sur le substrat sacrificiel (502), en for-

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mant des ouvertures (506, 516) dans la couche de masquage, et en déposant au moins une couche (524) d'un matériau métallique dans les ouvertures.

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15. Procédé selon la revendication 14, dans lequel :

le matériau métallique est choisi parmi le groupe constitué :

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du nickel et de ses alliages ;
du cuivre, du cobalt, du fer et de leurs alliages ;
de l'or, de l'or dur et de l'argent ;
des éléments du groupe du platine ;
des métaux nobles ;
des métaux semi-nobles et de leurs alliages, en particulier des éléments du groupe du palladium et de leurs alliages ;
du tungstène, du molybdène et d'autres métaux réfractaires et de leurs alliages ; et
de l'étain, du plomb, du bismuth, de l'indium et de leurs alliages.

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16. Procédé, selon la revendication 1, dans lequel :

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les structures à pointes de contact (720) sont allongées et sont effilées ou biseautées dans une première direction d'une première extrémité à une extrémité opposée de ces dernières.

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17. Procédé selon la revendication 16, dans lequel :

les structures à pointes de contact sont effilées dans une autre direction, orthogonales par rapport à la première direction à partir d'une première extrémité vers l'extrémité opposée de ces dernières.

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18. Procédé selon la revendication 1, comprenant en outre :

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la fourniture de chacune d'une pluralité de structures à pointes de contact (520) dotées d'une caractéristique de contact qui est précisément située par rapport aux caractéristiques de contact topologiques sur d'autres de la pluralité de structures à pointes de contact.

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19. Procédé d'interconnexion de deux composants électroniques comprenant :

la fabrication d'éléments d'interconnexion allongés (540) sur l'un des deux composants électroniques ;

la fabrication des structures à pointes de contact (520) sur un substrat sacrificiel (502) dans lequel les structures à pointes de contact comprennent des cantilevers ou poutres-consolés ;
par la suite, le raccordement des structures à pointes de contact (520) aux éléments d'interconnexion allongées (540) et le retrait du substrat sacrificiel (502) ; et

la poussée des structures à pointes de contact (520) contre les bornes correspondantes sur un autre des deux composants électroniques.

20. Procédé selon la revendication 19, dans lequel :

l'un des deux composants électroniques (254) est un dispositif à semi-conducteur.

21. Procédé selon la revendication 20, dans lequel :

le dispositif à semi-conducteur est un circuit intégré à application spécifique (CIAS).

22. Procédé selon la revendication 20, dans lequel :

le dispositif à semi-conducteur est un microprocesseur.

23. Procédé selon la revendication 19, dans lequel :

l'un des deux composants électroniques (254) est un composant d'un ensemble de carte à sonde.

24. Procédé selon la revendication 19, dans lequel :

l'un des deux composants électroniques (254) est un transformateur d'espacement d'un ensemble de carte à sonde.

25. Procédé selon la revendication 19, dans lequel :

l'autre des deux composants électroniques est un dispositif à semi-conducteur.

26. Procédé selon la revendication 19, dans lequel :

l'autre des deux composants électroniques est un dispositif à semi-conducteur résidant ou déposé sur une tranche ou rondelle à semi-conducteur.

27. Procédé selon la revendication 26, dans lequel :

le dispositif à semi-conducteur est un dispositif de mémoire.

28. Procédé de formation d'une pluralité de structures à pointes de contact sur un substrat sacrificiel (702), comprenant :

la fabrication d'éléments d'interconnexion allongés (540) sur un composant électronique ;
la préparation d'un substrat sacrificiel (502) en formant un mécanisme de dégagement ou de libération (522) sur une surface de ce dernier et en définissant une pluralité d'emplacements sur lesquels la pluralité de structures à pointes de contact sera fabriquée ;
la fabrication de la pluralité de structures à pointes de contact (520) au niveau de la pluralité d'emplacements sur le substrat sacrificiel préparé (502), dans lequel les structures à pointes de contact comprennent des cantilevers ou poutres-console ; et
par la suite, le raccordement des structures à pointes de contact (520) aux extrémités des éléments d'interconnexion allongés (540).

29. Procédé selon la revendication 28, dans lequel :

le mécanisme de dégagement ou de libération est adapté, en usage, pour dégager les structures à pointes de contact (520) du substrat sacrificiel (502) par un procédé choisi parmi le groupe constitué de l'attaque par la chaleur et l'attaque chimique.

30. Procédé selon la revendication 28, dans lequel :

le substrat sacrificiel (502) est préparé avec des caractéristiques topologiques situées précisément à l'intérieur de chacun de la pluralité des emplacements.

31. Procédé selon la revendication 28, dans lequel :

les structures à pointes de contact (520) ont des couches multiples, une première couche d'un matériau sélectionné pour sa résistance de contact supérieure, une couche finale d'un matériau sélectionné pour sa raccordabilité, et une couche intermédiaire d'un matériau sélectionné pour son intégrité structurelle.

32. Procédé selon la revendication 28, dans lequel :

le substrat sacrificiel est un substrat en silicium ;
le substrat en silicium est préparé par :

le dépôt d'une couche d'aluminium sur une surface d'un substrat en silicium ;

le dépôt d'une couche de cuivre en haut de la ou sur la couche d'aluminium ;
le dépôt d'une couche de matériau de masquage en haut de la couche de cuivre ; et
le traitement de la couche de masquage pour avoir une pluralité d'ouvertures à la pluralité d'emplacements, lesdites ouvertures s'étendant à travers la couche de masquage sur la couche de cuivre sous-jacente ; et

la pluralité de structures à pointes de contact est fabriquée sur le substrat en silicium préparé par :

le dépôt d'une couche de nickel à l'intérieur des ouvertures sur la couche de cuivre ; et
le dépôt d'une couche d'or sur la couche de nickel.

33. Procédé selon la revendication 32, dans lequel :

la couche d'aluminium présente une épaisseur d'environ 2 000 nm (20 000 Å) ;
la couche de cuivre présente une épaisseur d'environ 500 nm (5 000 Å) ;
la couche de masquage présente une épaisseur d'environ 51 µm (2 mils) ; et
la couche de nickel présente une épaisseur comprise approximativement entre 25,4 et 38 µm (1,0 et 1,5 mils).

34. Procédé selon la revendication 32, comprenant en outre :

avant le dépôt de la couche d'aluminium, le dépôt d'une couche de titane sur la surface du substrat en silicium.

35. Procédé selon la revendication 32 comprenant en outre :

avant de déposer la couche de nickel, le dépôt d'une couche d'un métal noble sur la couche de cuivre.

36. Procédé selon la revendication 28, dans lequel :

le substrat sacrificiel est en aluminium ;
le substrat en aluminium est préparé par :

le dépôt d'une couche de matériau de masquage sur une surface du substrat en aluminium ; et
le traitement de la couche de masquage pour avoir une pluralité d'ouvertures à la pluralité d'emplacements, lesdites ouvertures s'étendant à travers la couche de mas-

- quage sur le substrat en aluminium sous-jacent ; et
- la pluralité de structures à pointes de contact est fabriquée sur le substrat en aluminium préparé par :
- le dépôt d'une couche fine d'or dur sur le substrat en aluminium à l'intérieur des ouvertures ;
le dépôt d'une couche relativement épaisse de nickel sur la couche d'or dur ; et
le dépôt d'une couche fine d'or doux sur la couche de nickel.
37. Procédé selon la revendication 36, dans lequel :
- la couche d'or dur présente une épaisseur d'environ 2,54 μm (100 micropouces) ;
la couche de nickel présente une épaisseur d'environ 51 μm (2 mils) ; et
la couche d'or doux présente une épaisseur d'environ 2,54 μm (100 micropouces).
38. Procédé selon la revendication 36, comprenant en outre :
- avant de déposer la couche de nickel, le dépôt d'un précuivrage léger très fin sur la couche d'or dur.
39. Procédé selon la revendication 36, comprenant en outre :
- la fourniture d'un substrat en aluminium doté d'une feuille de doublage ou de support.
40. Procédé selon la revendication 28, dans lequel :
- le substrat sacrificiel est un substrat en silicium ; et
le substrat en silicium est préparé par :
- la formation de figures ou puits d'attaque dans le substrat en silicium à des emplacements spécifiques sur lesquels on souhaite avoir des caractéristiques topologiques sur les structures à pointes de contact qui seront fabriquées ;
l'application d'une couche de masquage et le modelage de la couche de masquage afin d'avoir des ouvertures à des emplacements sur lesquels les structures à pointes de contact seront fabriquées.
41. Procédé selon la revendication 28, dans lequel :
- le mécanisme de dégagement ou de libération
- est un matériau hydrofuge déposé sur la surface du substrat, et un matériau de non mouillage déposé sur le matériau hydrofuge.
42. Procédé selon la revendication 41, comprenant en outre :
- le dépôt d'une seconde couche du matériau hydrofuge sur la couche du matériau de non mouillage.
43. Procédé selon la revendication 42, comprenant en outre :
- le dépôt d'une seconde couche du matériau de non mouillage sur la seconde couche du matériau hydrofuge.
44. Procédé selon la revendication 43, comprenant en outre :
- le dépôt d'une couche barrière sur la seconde couche du matériau de non mouillage.
45. Procédé selon la revendication 28, dans lequel :
- le substrat sacrificiel est un substrat en silicium ; la pluralité de structures à pointes de contact est fabriquée sur le substrat en silicium préparé par :
- le dépôt d'une couche d'aluminium, suivi du dépôt d'une couche de chrome, puis du dépôt d'une couche de cuivre, puis du dépôt d'une couche d'or.
46. Structures à pointes de contact adaptées en usage pour le raccordement aux extrémités correspondantes des éléments d'interconnexion allongés qui s'étendent à partir des bornes sur une surface d'un substrat, comprenant :
- une pluralité de structures à pointes de contact (520) fabriquée et résidant sur un substrat sacrificiel (502) à des positions prédéterminées sur le substrat sacrificiel ;
- dans lesquelles, en usage, le substrat sacrificiel (502) est séparé des structures à pointes de contact (520) après le raccordement des structures à pointes de contact aux extrémités correspondantes des éléments d'interconnexion allongés qui s'étendent à partir d'une pluralité correspondante de bornes du substrat, dans lequel les structures à pointes de contact chacune comprend un cantilever ou une poutre-console.
47. Structures à pointes de contact préfabriquées adap-

tées en usage pour réaliser les connexions de masquage aux extrémités correspondantes des éléments d'interconnexion allongés qui s'étendent à partir des bornes d'un composant électronique, comprenant :

une pluralité de structures à pointes de contact métalliques formées sur un substrat sacrificiel (502), lesdites structures à pointes de contact adaptées en usage pour être raccordées aux extrémités correspondantes des éléments d'interconnexion allongés qui s'étendent à partir des bornes du composant électronique, dans lequel les structures à pointes de contact (520) comprennent chacune un cantilever ou une poutre-console, et dans lequel les structures à pointes de contact sont adaptées pour effectuer des connexions électriques entre le composant électronique et un autre composant électronique ayant le substrat sacrificiel retiré.

48. Structures à pointes de contact préfabriquées, selon la revendication 47, dans lesquelles :

les structures métalliques sont des structures métalliques à couches multiples ;
le substrat sacrificiel est une feuille de métal ;
le métal est l'aluminium ;
le substrat sacrificiel est une tranche ou pastille en silicium ;
le substrat sacrificiel est un matériau choisi par le groupe constitué de l'aluminium, du cuivre et du silicium.

49. Structures à pointes de contact préfabriquées selon la revendication 47, dans lesquelles :

les structures métalliques sont d'une ou de plusieurs couches d'un matériau choisi parmi le groupe constitué :

du nickel et de ses alliages ;
du cuivre, du cobalt, du fer et de leurs alliages ;
de l'or (spécialement de l'or dur) et de l'argent, tous les deux présentant d'excellentes capacités de conductivité du courant et des bonnes caractéristiques de résistivité de contact ;
des éléments du groupe du platine ;
des métaux nobles ;
des métaux, semi-nobles et de leurs alliages, en particulier des éléments du groupe du platine et de leurs alliages ;
du tungstène, du molybdène et d'autres métaux réfractaires et de leurs alliages ; et
de l'étain, du plomb, du bismuth, de l'indium et de leurs alliages.

50. Structures à pointes de contact préfabriquées selon la revendication 47, dans lesquelles :

chaque structure métallique a une topologie sur une surface de cette dernière ; et
la surface ayant une topologie est celle qui, en usage, effectue une connexion de pression aux bornes des autres composants électroniques.

51. Procédé, selon la revendication 1 ou 19, comprenant en outre la fourniture d'une tranchée (1012) dans la surface du composant électronique (1010) adjacent à une partie allongée de la structure à pointes de contact (1000).

52. Procédé selon la revendication 1 ou 19, comprenant en outre la fourniture d'une structure (1032, 1052) entre la surface du composant électronique (1030, 1050) et une partie allongée de la structure à pointes de contact (1020, 1040).

53. Procédé selon la revendication 52, dans lequel ladite structure (1052) enveloppe une partie (1042) de la structure à pointes de contact (1040).

54. Procédé selon la revendication 1 ou 19, dans lequel une partie allongée de la structure à pointes de contact comprend un pli ou un coude (1072).

55. Procédé selon la revendication 54, dans lequel le pli (1072) est disposé vers la surface du composant électronique (1070).

Figure 1A

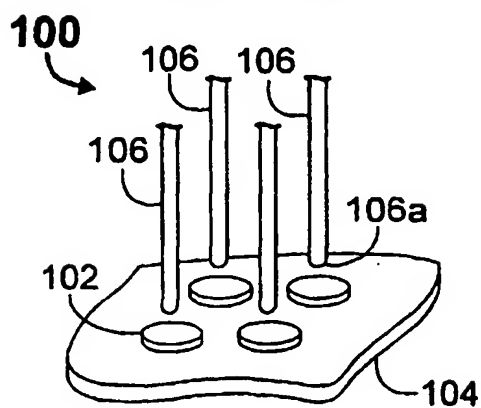


Figure 1B

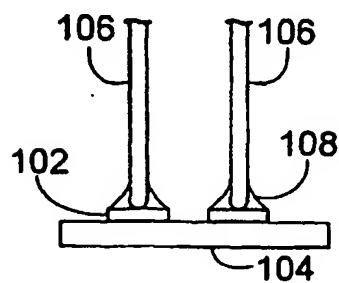


Figure 1C

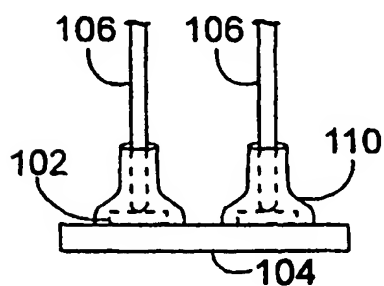


Figure 1D

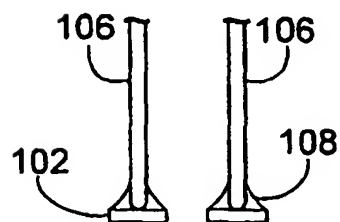


Figure 2A

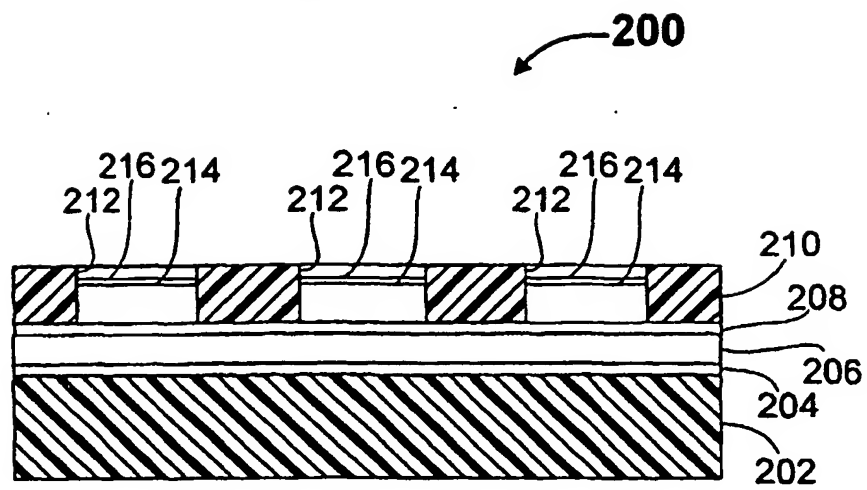


Figure 2B

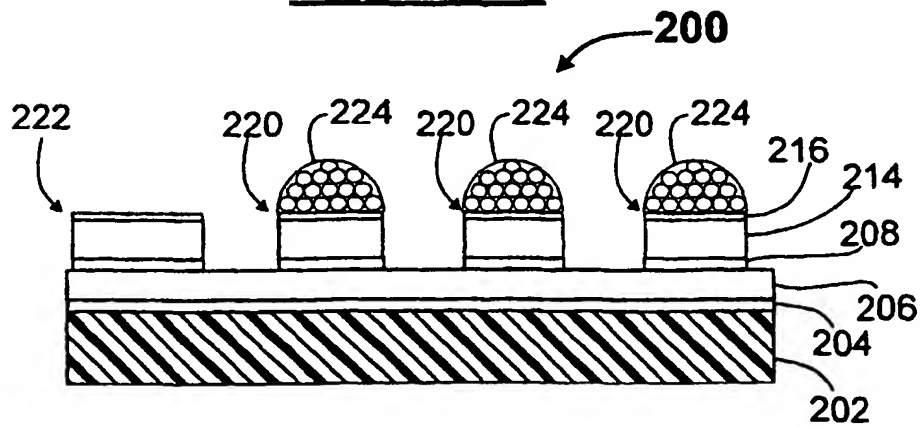


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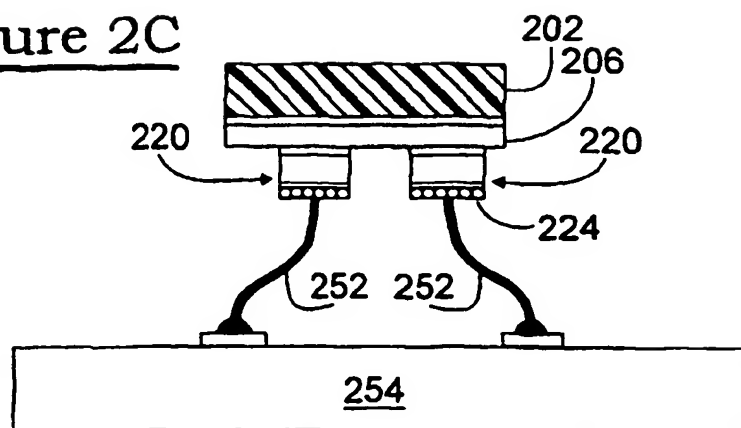


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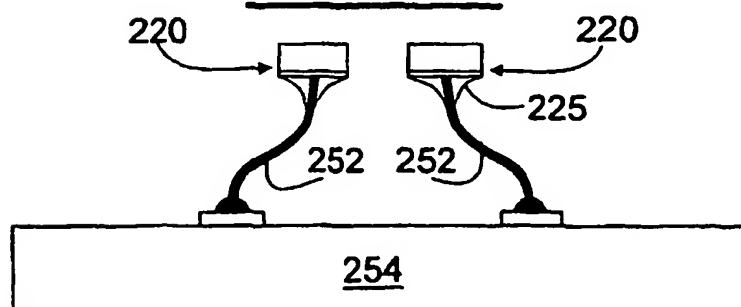


Figure 3A

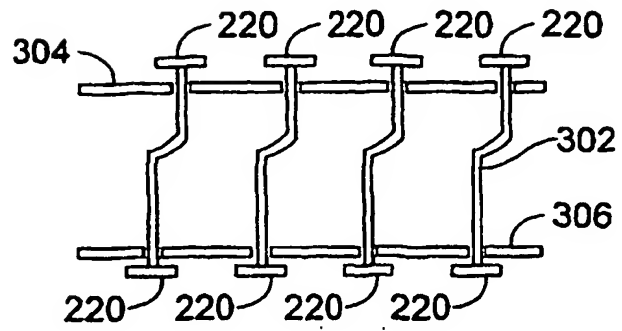


Figure 3B

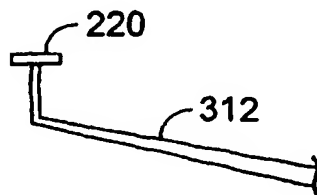


Figure 3C



Figure 4A

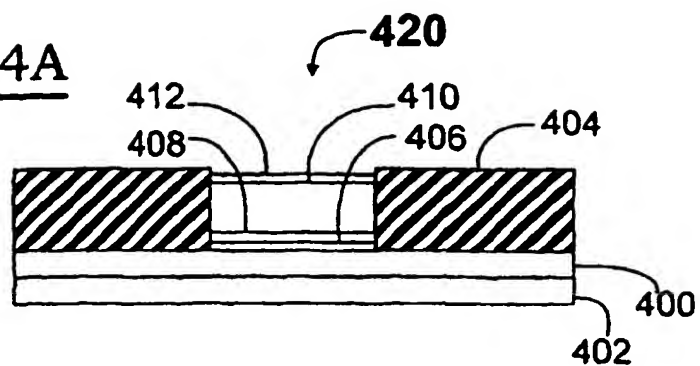


Figure 4B

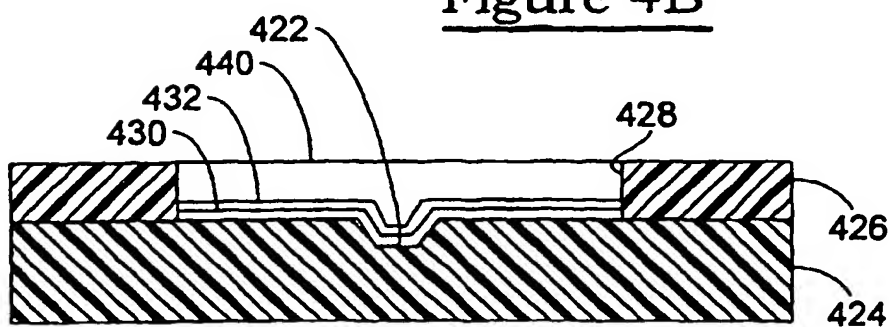


Figure 6A

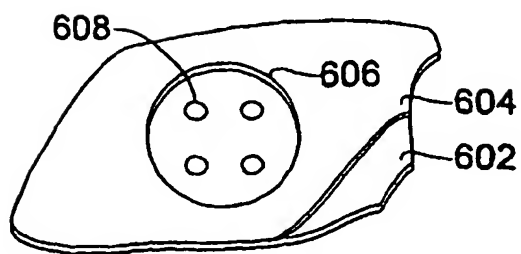


Figure 6B

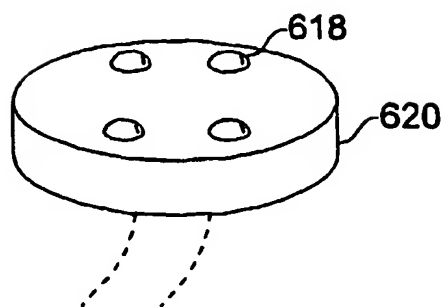


Figure 5A

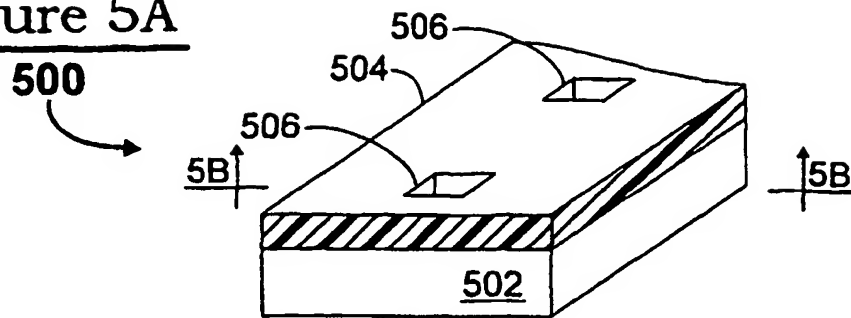


Figure 5B

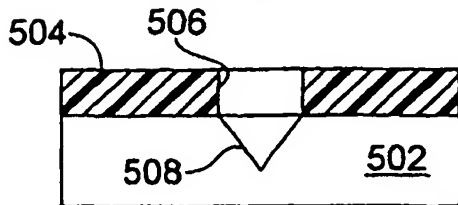


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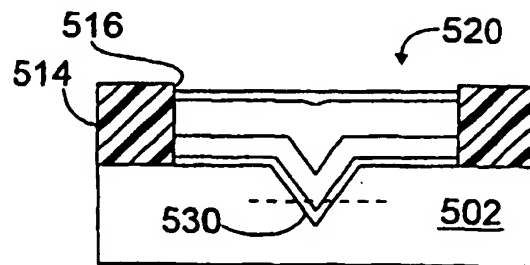


Figure 5D

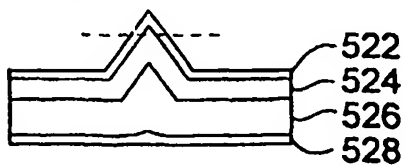


Figure 5E

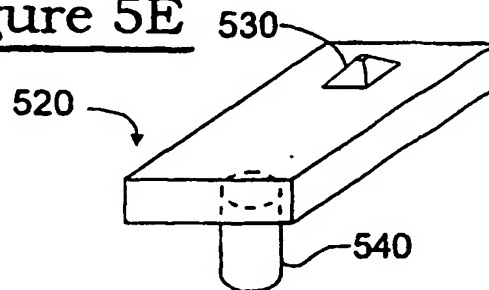
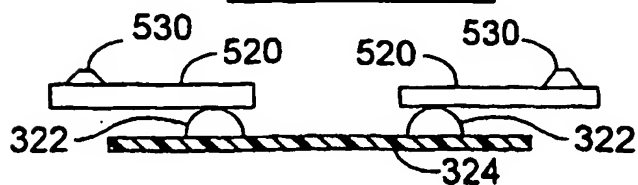


Figure 5F



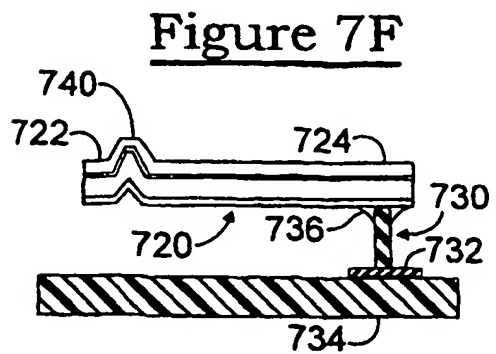
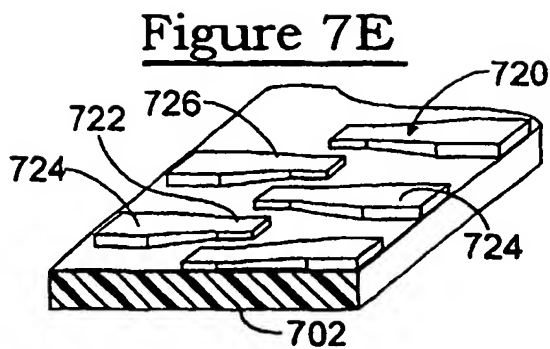
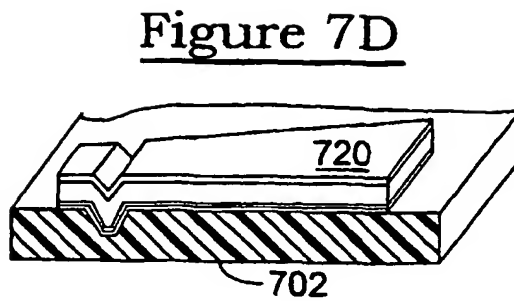
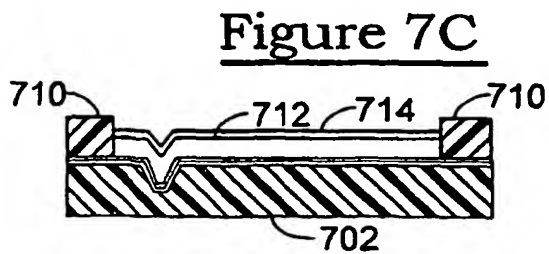
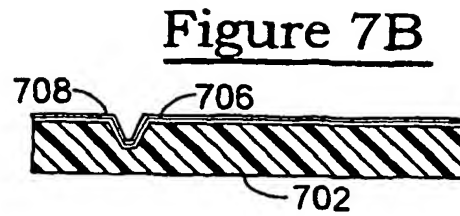
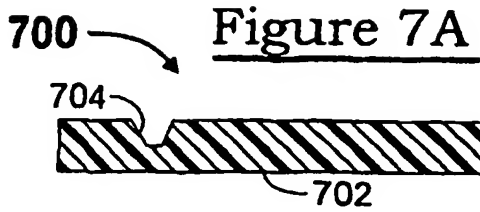


Figure 8

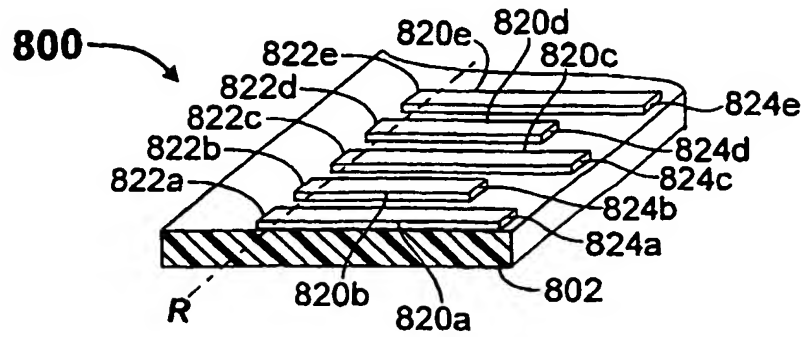


Figure 10A

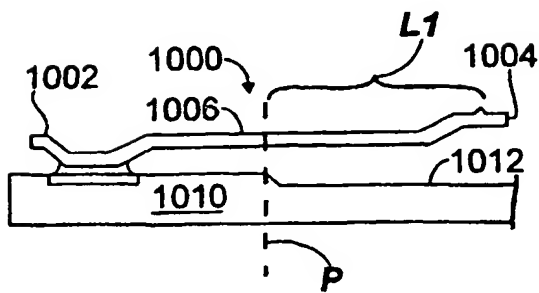


Figure 10C

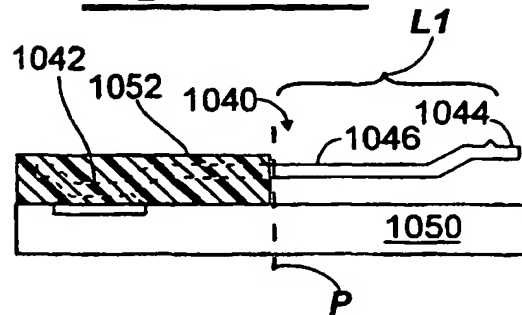


Figure 10B

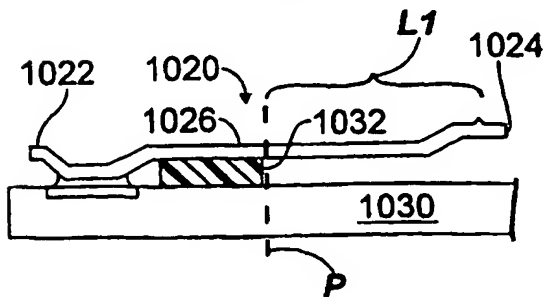
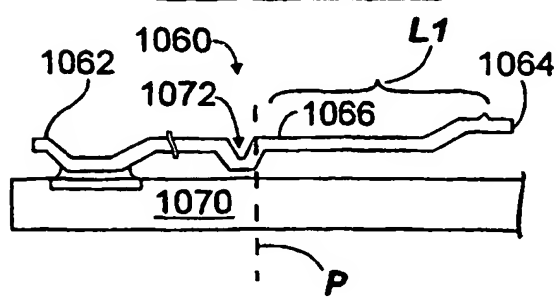


Figure 10D



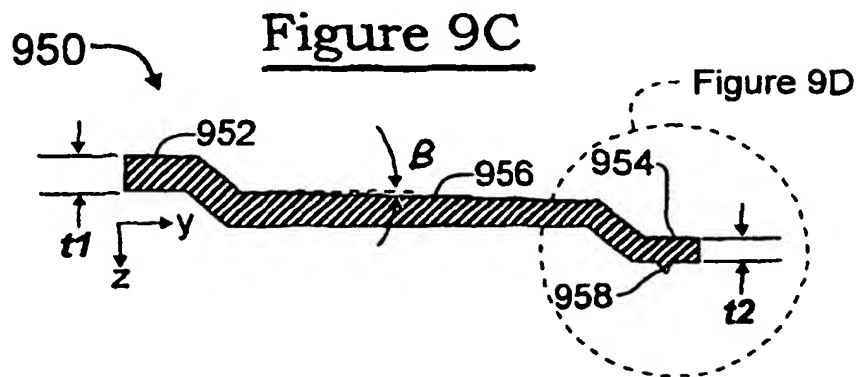
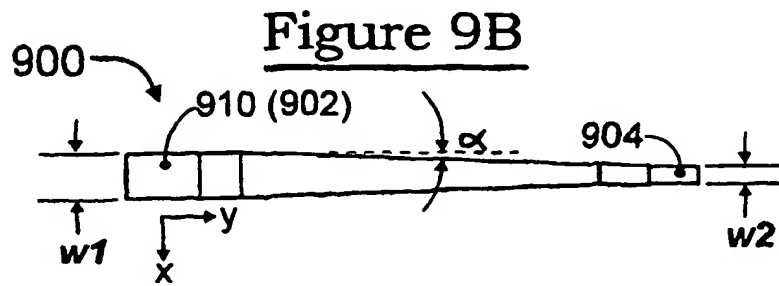
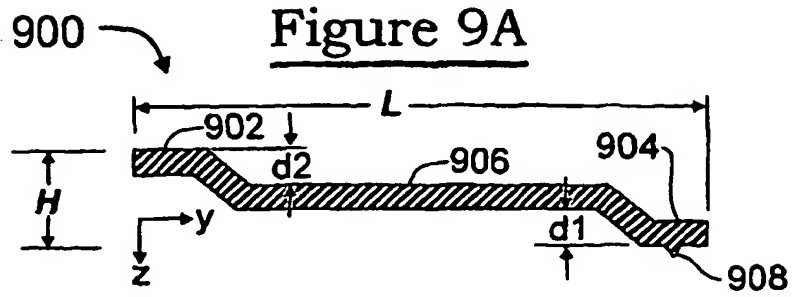


Figure 9D

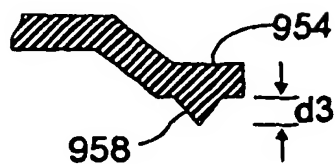
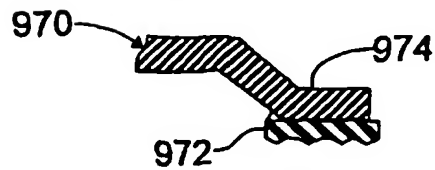
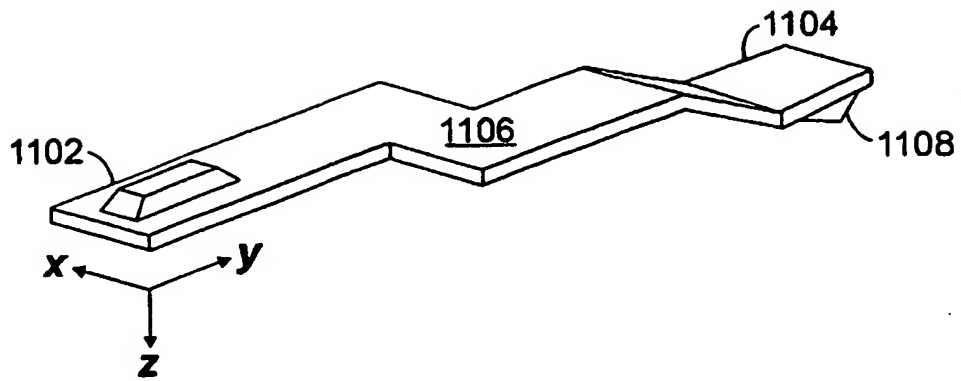


Figure 9E



1100 Figure 11A



1150 Figure 11B

